WHO FAO UNEP

VBC / 87.3
ENGLISH ONLY
Distr.: LIMITED

PEEM III
PEEM IV
PEEM V
PEEM VI

selected working papers prepared for the 3rd, 4th, 5th, and 6th meeting of the WHO/FAO/UNEP Panel of experts on Environmental Management for Vector Control (PEEM)

PEEM Secretariat
World Health Organization
GENEVA, 1987

WHO FAO UNEP

JOINT WHO/FAO/UNEP PANEL OF EXPERTS
ON ENVIRONMENTAL MANAGEMENT FOR VECTOR CONTROL

VBC/87.3
LIMITED
DISTRIBUTION

SELECTED WORKING PAPERS FOR THE THIRD, FOURTH, FIFTH AND SIXTH PEEM MEETING

PEEM Secretariat
World Health Organization
Geneva, 1987

PREFACE

With the publication of this document, containing a selection of the original working papers prepared for the PEEM meetings held between 1983 and 1986, a long-standing recommendation of the joint WHO/FAO/UNEP Panel of Experts on Environmental Management for Vector Control (PEEM) has been implemented.

The World Health Organization, the Food and Agriculture Organization of the United Nations and the United Nations Environment Programme established the Panel in 1981, with the objective to strengthen collaboration between the three agencies, and to promote collaboration with other appropriate international and national agencies, in their programmes and projects relating to natural resources, agricultural and health development, and in the use of environmental management techniques for the control of disease vectors and the protection of human health and the environment.

Since its inception, the Panel's modus operandi has been to review and revise its programme of work at annual meetings; always included in the agenda of these meetings has every year been a technical discussion, on a specific subject within the Panel's mandate. While the programme of work defines, in order of priority, recommended activities to be carried out by the three organizations under the auspices of the Panel, the technical discussions aim to determine the state of the art of a specific subject, to identify research and training needs within the scope of the subject, and to disseminate the information collected to professionals in the relevant public sectors of all Member States, and in international organizations. Conclusions and recommendations resulting from the technical discussions address WHO, FAO and UNEP, but also multilateral and bilateral agencies, development banks and nongovernmental organizations, to promote policy and programme changes favouring more sustainable water resource development.

Over the years, the PEEM technical discussions have become a more prominent item on the Panel's agenda. At the first meeting (Geneva, 1981), less than a day was devoted to the technical discussion session, and the conclusions and recommendations appeared as an annex to the report, together with the unabridged versions of the working papers. At the most recent meetings, the Panel dedicated two and a half days to this agenda item, and the technical discussion section has, since 1986, become the most prominent part of the report.

The discussion is based on a number of working papers, prepared by Panel members or by temporary advisers with special expertise in the subject. At the start no more than three working papers were commissioned for a meeting, and they were reproduced integrally in the report. Later on, the technical discussion section reflected better the deliberations of the Panel, drawing on the working papers for facts and illustrative examples only. This developed to the extent where in 1987 FAO published the working papers prepared for the 7th PEEM technical discussion in a separate document (AGL/MISC/87/12) in addition to the annual meeting report containing the Panel's deliberations, conclusions and recommendations.

The idea to publish a selection of working papers was raised for the first time in 1984, and at its seventh meeting the Panel officially added this item to the PEEM publication programme.

While the papers presented in this document have to some extent been updated as part of overall editing, they should be read with the year in which they were prepared in mind. Each section is preceded by a brief introduction recalling the major recommendations resulting from the discussion of the papers, and the developments that have been taking place since. Added to the original bibliographic references is a selection of references to literature that has appeared since their preparation.

Some of the papers take us back to the simple origins of an issue that has since then developed to a subject of greater complexity. Others put on record certain organizational structures as they existed at the time, and which by now have changed as a result of restructuring and political change. Compiled together in this document, these papers once more draw attention to four crucial issues in the field of water resource development associated vector-borne disease problems: the need for proper forecasting and monitoring of the effects of development on human health, the importance of good institutional arrangements between the sectors involved, the attention required for the resettlement and population migration component of development projects, and the provision of a sound economic basis for the incorporation of health safeguards in water resource development.

Robert Bos
Secretary,
Geneva, 1988

CONTENTS

WHO FAO UNEP

PEEM 1983

METHODS OF FORECASTING THE VECTOR-BORNE DISEASE IMPLICATIONS IN THE DEVELOPMENT OF DIFFERENT TYPES OF WATER RESOURCES PROJECTS

A first condition for including environmental management measures as health safeguards in water resource development projects is the availability of a reasonably accurate picture of the epidemiological changes as they will occur during project implementation. It is therefore not surprising that the Panel dealt with the subject of forecasting methods at one of its early technical discussions. Epidemiological changes will be the result of ecological changes, induced by a modified hydrology, and demographic changes. The latter subject, which includes resettlement, temporary labour, and planned or unplanned migration, was covered at the fifth PEEM meeting.

The objectives of health risk assessment in this context are:

- to provide the basis for the introduction of modifications in project design and management at the planning stage;
- to formulate the strengthening needs of national health services so they can deal adequately with expected health situation;
- to use the expected level of perceived health risks as an indicator for the sustainability of a particular development project; and
- to use the outcome of the assessment as a criterion for the selection of areas for development projects.

The papers presented here reflect the state of the art at the time of the discussion: health impact assessment methods were mere adaptations of more advanced environmental impact assessment techniques. In its conclusion, the Panel recommended the development of a specific forecasting method for the vector-borne disease implications of water resources projects. It was recognized that, for the time being, such a method could not be but qualitative. The need for continued health monitoring to follow any forecasting exercise was also stressed.

Following the meeting, the preparation of guidelines for forecasting were commissioned from Dr M.H. Birley of the Liverpool School of Tropical Medicine. A preliminary draft version was published three years later (Birley, 1987), proposing a flowchart methodology for the prediction of three distinct components: the disease situation, the transmission potential and the disease management effectiveness. The guidelines were fieldtested in Zambia (1986) and in Thailand and Malaysia (1988). The final version is expected to be published by mid-1989.

In the field of environmental impact assessment (EIA) progress has been made the last few years in adapting methods to the needs of developing countries (ADB, 1986; Biswas and Geping, 1987). Development banks have continued to enforce their policy that an EIA must be part

of a development project's feasibility study. Lack of EIA experts in the developing countries remains, however, a serious constraint. Also, implementation of EIA recommendations and monitoring of the situation during construction and operation often fail to materialize.

Valuable experience was gained from the World Bank project "Options and Investment Priorities in Irrigation Development" (World Bank, 1987). Nine rapid assessments of the irrigation potential were carried out in different parts of the world, on the basis of available data, each one including a health component. At a workshop in Paris in July 1987 to review the outcome of the health risk assessments, the need for monitoring and the role of the health sector in this exercise were once again emphasized. Other needs identified: the formulation of some general typifications, the production of risk maps and better accessibility of relevant databases.

A next phase in forecasting will probably include the application of Expert System technology. Access to personal computers has rapidly increased during the 1980s, and software has been developed to the level where a dedicated Expert System for forecasting can be made available on a diskette. The use of this knowledge-based decision-making tool at the prefeasibility stage of a project will help engineers to determine how and with which focus an in-depth health risk assessment can effectively be included at the feasibility stage. While the introduction of this high technology raises great expectations, it may be good to bear in mind the simple principles on which a forecast should be based and which are discussed in the following papers.

ECOLOGICAL FACTORS IN THE PREDICTION OF VECTOR-BORNE DISEASES AS THEY MAY RESULT FROM WATER RESOURCE DEVELOPMENT

by

E. Barton Worthington

INTRODUCTION

Ecology, for the purposes of this paper, has to take account of all factors which influence changes in the environment, whether natural or man-made. The environment is made up of the physical, chemical, biological and human conditions all of which react with each other to form a series of ecosystems which can be defined, to a certain extent, but which generally have blurred boundaries. An example is the boundary between an aquatic and a terrestrial ecosystem, composed of a swampy strip which, if extensive, becomes a separate ecosystem on its own and one of great importance to the subject of this paper. In almost any water project the pre-existing complex of ecosystems needs to be assessed before the planning and design stages commence, for only then can predictions be made of what will happen during the construction and management phases.

As a basis for attempting to define the factors involved in such predictions, it is desirable to place the present state of ecology in its historical perspective. It had its roots in nineteenth century Natural History, and the first quarter of the twentieth century may be described as the formative phase of ecology as a scientific discipline. Initially the focus was mainly on vegetation - but in medicine this period and the years just before it saw great discoveries, including the part played by insects as vectors of malaria, trypanosomiasis, and filariasis and by snails as intermediate hosts of schistosomiasis.

During the second quarter of this century ecology was mainly descriptive. Masses of data were collected and interpretations were proposed. Some of them pointed to land and water management as a means of controlling vector-borne diseases.

The third quarter saw ecology developing as an experimental science, a development which culminated in the International Biological Programme (1964-74). Meanwhile the widespread use, and sometimes abuse, of toxic chemicals had a big effect on the environment and stimulated public interest. This period also saw the emergence of human ecology, recognising that our own species is the major predator on other animals and plants and is coming rapidly to dominate and to alter almost all the environments on earth.

During the current fourth quarter, ecology is becoming predictive and there is a great opportunity for applying the results of past study. Unless that process goes faster than at present, the forebodings of doom-watchers concerning the twenty-first century may well be realised. It

Dr E. Barton Worthington is an environmental consultant based in the U.K.

would seem that many opportunities for successful application are missed because the best ecologists are apt to spend their lives on fundamental research. If they would deploy more effort in examining how their results could be used for human and environmental betterment, we could look forward with greater confidence.

Phases in the methodology of controlling vector-borne diseases have run in parallel with the development phases of ecology. As Bradley and others pointed out during the Symposium on Engineering, Science and Medicine (London, 1978), in the wake of medical biologists came engineers and technicians who applied environmental methods - water supply and sewage disposal, drainage of swamps, planting trees with high evapotranspiration, and construction of vector-proof buildings. This was the vogue until the middle of the century when the synthetic chemicals took over for both vector control and disease therapy, and environmental methods went into eclipse. However, during the third quarter of the century the development of resistance to toxic chemicals by both vectors and pathogens has shown that chemistry by itself is not enough, and it is good news that the ecological approach is being brought back into prominence.

PREDICTION

Real progress consists in the selection of tractable parts of the subject and working through to their solution. But since the ecological factors are more often than not interdisciplinary, some problems may appear intractable and there is a danger of lapsing into generalities.

To some extent generalities are necessary owing to the difficulty of specifying, because, however good the technology, the success of the prediction and of subsequent control of a disease depends so much on local human factors. In irrigation projects,for example, there has been a tendency until quite recently to focus heavily on the engineering and technical aspects and to assume that, given adequate housing and related facilities, the people who live and work on it, often in a completely strange environment, will sort out their own practical and social problems. During the International Symposium on Arid Land Irrigation: Problems and Environmental Effects (Alexandria, 1976) the question was apt to be asked: are irrigation schemes made for people, or are people made to fit the schemes? This kind of question is followed up below in the section on human ecology.

In predictive ecology, the techniques of systems analysis using mathematical models which are now being applied to ecosystems have proved useful. Such techniques were, however, designed originally for the solution of engineering and related problems where the measurement or estimation of factors has a much higher degree of accuracy than is possible with many of the variables of living nature.

Another technique, now much in vogue at the planning stage of projects, is that of the environmental impact statement (EIS) about which a number of books have already been written. There is no doubt that the frequent insistence by donor agencies that every new project be accompanied by an EIS has helped greatly in avoiding environmental mistakes. One can, however, devise many questions and feed the answers into a computer; the printout is often useful, but it can also be misleading because there are so many factors and variables involved. To ask the right questions needs much experience.

Environmental Impact Statements tend to emphasise undesirable effects and thus to be somewhat negative documents unless handled intelligently. The very word ''impact'', which suggests a clash, is in the author's view inappropriate, because the environment reacts to change by adaptation, often slowly, and only rarely by clashes, even though the convergence of two opposing interests on a collision course is not unknown. An EIS should indicate how the beneficial effects can be magnified as well as how the undesirable ones can be avoided or minimized.

For these reasons one must conclude that, while systems analysis and EIS are useful tools in the right hands, ecological experience counts for more than formalised catechisms of question and answer or mathematical formulae. Unfortunately, however, experience, which should indicate which are the key critical factors, is often not available. Few if any large or small-scale water projects in developing countries have been followed through in a comprehensive way by monitoring data and information over a period of say 10 years, which is about the period it takes for major disruptions of the environment to settle down. Great sums of money are spent on initiating a scheme, say a man-made lake coupled with hydroelectric power generation and irrigation from the tail water; but very little is spent on assessing to what extent its main objectives are achieved, and how the ancillary effects fared. With regard to health, it generally takes an epidemic for a new study of conditions to be initiated. Only rarely has any serious study been undertaken of the social and behavioural changes undergone by the people concerned.

SOME FACTORS IN ENVIRONMENTAL CHANGE

In predicting the effects of each change to be made in the environment, the physical, chemical, biological and human components need to be separated as far as possible, especially those which will alter the feeding and breeding requirements of vectors. This is not easy when considering ecological factors, but there are cases where definite predictions can be made.

Take the case of onchocerciasis and its vector *Simulium damnosum* : it is well known that the vector's larvae can live only in water with a high oxygen content and rapid flow which brings food in the form of micro-organisms to the larval filtering apparatus. Thus when a reservoir is to be built on a stream with frequent rapids of ''white water'' in an oncho-area, one can predict with certainty that, when completed, there will be no *Simulium* breeding in the reservoir area, but probably a lot at the site of the spillway of the dam. Thus, by applying the purely physical change of impoundment, numerous breeding sites will be reduced to one where conditions of accessibility and hydrological measurement will make chemical control relatively easy and effective.

By contrast the various other species of mosquito vectors generally need still or nearly still water of higher biological productivity, and so do the snail intermediate hosts which graze or browse off sessile organisms and usually need waterweeds as substrate both for food supply and egg-laying. Biological productivity depends on the levels of natrium, potassium and a few other elements in water as in soil. The nutrient salts which occur naturally may be enhanced by fertilizers escaping from land nearby or from animal and human waste. Such factors can sometimes be quantified.

It could be claimed that research on the environmental needs of all likely vectors associated with water projects is at a well-advanced stage today. If the physical and chemical changes

created by a water project can be predicted with reasonable accuracy, there should be no great difficulty for an experienced aquatic ecologist to give a fair idea of how the populations of vectors are likely to respond. Before reaching a more or less "steady state", however, quite dramatic changes may take place in the aquatic ecology, for example, where a new reservoir is constructed or canals are filled with water in an irrigation scheme.

First, to consider the marginal and shallow water environment: when land is inundated there is generally a period of up to 10 years in temperate countries, less in the tropics owing to the rapidity of living processes, during which vegetable and animal life in the water is subject to a succession of changes. In Southern England a frequent succession of rooted vegetation would be star-wort (*Asterionella*) during the first year or two, followed by Canadian water-weed (*Elodea canadensis*) and later species of pondweed (*Potamogeton*), and if the water is not too acid, water buttercup, each becoming dominant. Water plantain (*Alisma*) and other emergent vegetation appear from the second or third year after mud has accumulated. Each plant association harbours different associations of invertebrate animals, including potential vectors such as snails and mosquitoes.

At first the inundated soil usually gives off a rich supply of nutrients and animals are drowned out; food chains of invertebrata develop quickly one after the other and provide a bonanza of food for a fish population which expands very rapidly for perhaps a couple of years. As mud accumulates on the bottom, the substrate is apt to become anoxic, nutrients are less available and vegetation is reduced. If a reservoir is emptied after a number of years, the bottom deposits regain oxygen and accumulated nutrients become available. When refilled, the original succession is likely to be repeated. Meanwhile in the open water there will be a separate series of biological changes in the plankton and nekton.

Once the "steady state" is reached after the early convulsive years, a relatively slow but continuous process of eutrophication takes over and this process is liable to acceleration if the waterbody receives some form of fertilization from outside. Rooted vegetation invades, especially around the margin, and may provide new habitats for vectors.

In the tropics, much less is known about such successional changes after inundations, but the burst of high biological production during the first few years, giving rise to large fisheries and probably to large populations of snails and insect larvae, is well known.

The floating vegetation in the tropics, which may give harbourage to vectors, includes the very serious pest species water hyacinth (*Eichhornia crassipes*) and waterfern (*Salvinia auriculata* and *S. molesta*), both of which originally reached Africa and other tropical areas from South America. Like other floating water plants, including the Nile Cabbage (*Pistia stratiotes*) which is indigenous to African rivers and lakes, the roots of *Eichhornia* and *Salvinia* contain air. This supply of gaseous oxygen below the water surface is used by larvae of mosquito species of the genus *Mansonia* , thereby avoiding the necessity of breaking the water's surface film. In the pre-DDT days, when the application of Paris Green on the water surface was a common mosquito control method killing mosquito larvae as they surfaced, the presence of *Pistia* was a great nuisance. The author does not know whether similar trouble is associated with the recent invasions of *Eichhornia* and *Salvinia* , but certainly the former has raised great problems for engineers by blocking sluices at reservoirs.

Eichhornia 's spread through Africa is an interesting example of ecological prediction. It first appeared in the Congo River in the late 1940s where it caused great damage to fisheries and incommoded transport. It soon spread to a large part of Southern Africa; ecologists predicted that it would appear before long in the Upper Nile and would quickly spread downstream, so that those in charge of water control works should be prepared. The first specimens were spotted in that river by a botanist working at Khartoum University during the 1950s; it had a big population explosion and caused consternation. The author is not sure, however, in how far *Eichhornia* was then or is now associated with vector breeding and vector-borne disease transmission.

It must be noted that, in addition to the aquatic vectors of diseases, certain terrestrial vectors have to be considered in predicting health and disease associated with water projects. Tabanid flies, which are semi-aquatic in that their larvae live only in wet soil or marshy conditions, can be pests both to man and beast. Some species are known to transmit a certain type of filariasis. House-flies and their relatives are of obvious importance and are specially associated with waste disposal which is often a problem in settlements associated with water projects. In Africa, the tsetse fly which favours the half-shaded bush vegetation near water (*Glossina palpalis*) could become a problem and so might *G. morsitans* and other dry-land tsetseflies in areas near settlements, unless well-established methods of fly control are rigorously applied in critical areas. In irrigation schemes, where it is a desirable trend to work animal industry into what often starts as pure stands of cotton, rice, or other grain crops, ticks may transmit vector-borne diseases, at least in animals if not in humans.

All the above may become problems, depending on the physical, chemical and biological changes caused by the project. Present ecological knowledge should be capable of predicting them with fair accuracy on the basis of experience elsewhere and after examination of the area concerned. The effectiveness of control measures is another matter which depends on the initial planning and construction, and subsequently on land and water management. If necessary, toxic chemicals may have to be used in addition.

In all water projects in warm countries, a good rule is to design and to maintain an abrupt margin between land and water areas. Whether one is dealing with the details of canals and small feeders in an irrigation scheme, or the margin of a reservoir, the land/water surface interface, if indistinct and swampy, is usually a major producer of vectors. In this connection, it is obviously a great advantage to be able to raise and lower the water level, which is a matter for initial design. Accidental and casual water spillage can be predicted without exception to create swampy conditions favourable to vector-breeding.

One branch of water management where prediction is still difficult involves fish. In man-made lakes and in many irrigation schemes which are intended primarily for rice production, fisheries are of great socio-economic importance. In some irrigation projects, specific areas for fish-raising in ponds are advocated as an economic use of water, but health authorities are apt to oppose this on the grounds that fish farming, unless very well managed and with a proper selection of fish species, is apt also to produce vectors of disease. Current knowledge of tropical freshwater fish in the various biogeographical regions in the world - their feeding and breeding habits, and other ecological requirements - is extensive. It is approaching the level where accurate prescriptions could be made for appropriate species of fish in the right proportions, in order to produce optimum crops and at the same time to control snail and insect vectors. Here again,

however, there is the human factor, in that local management of each water area is critical for success.

Another aspect is concerned with forestry and woodland management. Every water project which involves human settlements creates a demand for firewood and timber for building and fencing, and this frequently leads to devastation of nearby land, and consequent soil erosion and other troubles which get progressively worse as they spread outward. In consequence, some irrigation schemes, though regrettably few, at the planning stage include plantations of firewood and building poles around their margins, and sometimes on irrigated land within the scheme. Ideally, these should be sufficient in area to supply the needs of the scheme permanently on a rotational woodland management plan of cutting, followed by copicing or replanting. Few insect vectors in their adult stages prosper in a woodland with closed canopy; thus it could be predicted that shelterbelts of woodland surrounding or within an irrigation scheme can not only supply essential human needs but also reduce rather than enhance the risks from vectors of disease.

HUMAN ECOLOGY

Most discussion at the aforementioned Symposium on Arid Land Irrigation in Developing Countries (Alexandria, 1976) centered around technological questions, but a recurring theme was the farmer and his family. Whether settled on individual holdings or in various kinds of employment ranging from small-village schemes through government farms, plantations, to full-scale agri-businesses, the farmer's well-being, efficiency and social state are essential for success. Until a few years ago, however, little social study was undertaken among the people who were due to be enrolled as settlers, or to be displaced by a project, on how they would adapt to the new conditions, and what provision for their needs was required. It was relatively easy to predict that, unless careful attention was paid to drainage as well as to the supply of water, salination of the soil was probable, and that epidemics of malaria and schistosomiasis were possible, but it was not easy to predict what kind of settlement and village organization would suit the people concerned.

To take a simple example, piped water supply in the house has obvious advantages to western standards, but it is nevertheless a very recent facility even in European society. In less advanced economies, most women enjoy the social contacts involved in collecting water and washing clothes; it takes them out and about, and there are cases on record where house taps have been ignored in favour of the communal well or water hole. A stand-pipe is much cheaper to install and to maintain than several dozen house taps, and its spillage is more easily checked.

In predicting and arranging for human ecological and behavioural factors such as this, a major aim obviously must be to interrupt contact between vectors of disease and their human hosts. Snail intermediate hosts of schistosomiasis do no harm - indeed they could be useful in providing food for fish - if the water in which the people wash is free of schistosome larvae. With the aim of breaking the host-vector contacts, new human settlements necessary for a project have usually been constructed far away from streams, ponds and lakes. Has there not been a lack of appreciation that a great many people, especially fishermen, wish to live near water and by doing so provide an optimum environment for pathogens?

An outstanding example is provided by the early years of Lake Volta in Ghana where the socio-economic planning for displaced people was exceptionally thorough. It was assumed that they would happily settle in newly constructed villages, provided with good housing, agricultural land, clean water etc., all carefully sited and built in advance at a considerable distance from the lake shore. But these villages remained largely uninhabited for several years during which the displaced people together with many immigrant fishermen from elsewhere built their huts along the shoreline. They enjoyed a bonanza of fish, but the prevalence of *Schistosoma haematobium* infection, which was "low" before the project was completed in 1966, had risen to 90% two years later.

There are, of course, plenty of other examples where social behaviour, the likes and dislikes and taboos of particular human groupings, need to be taken into account in connection with vector-borne diseases. The point to be made is that the human ecological reactions of the people who live and work in connection with water projects need to be predicted and provided for at least as thoroughly as the biological, medical and economic factors.

CONCLUSIONS

Ecological prediction of the kind with which this paper is concerned is something of a cross between science and art. Many disciplines are involved and where one impinges on another the boundary is apt to be blurred. In recent years, there have been strong moves to give greater precision to ecology by introducing mathematical concepts under the title of systems analysis. Greater precision in the analysis of ecosystems, which has been an aim of ecology for most of a century, is of course important. Nevertheless, the experienced eye can sometimes make a better ecological assessment of what will happen as a result of environmental changes, natural or man-made, than the less experienced one working with equations.

Aside from the primary purpose of a water project, whether it be domestic supply, hydro-power, water storage, fisheries or irrigated agriculture, there are inevitably ancillary effects, both good and bad. Water-related diseases need to be considered as part of the overall effects of water on the environment of man, and many of these effects are beneficial. Relatively close rural settlement, as around an irrigation scheme, renders health and educational services more readily available.Areas of water, if properly managed, give opportunities for useful additions to food supplies. Water enhances wild plant and animal life and man-made lakes have in a number of cases helped in the creation of national parks and reserves which are assets to the tourist industry as well as of educational value.

Specifically concerning the water-related vectors of disease, it is not easy to separate the physical, chemical, biological and human ecological factors which are involved in prediction. Much study has been devoted to the auto-ecology of the vectors, less to the synecology of the ecosystems in which they flourish, less still to the human ecology of the people affected by the diseases.

Indeed, human ecology, which relates socio-economic factors to the changing environment and studies the adaptations of mankind thereto, is of great importance in connection with vector prediction, but still requires much guess-work. We are concerned here with the rural majorities in developing countries rather than the urban minorities, but as standards of urban planning

improve, with more open spaces including perhaps ponds and water channels, the standards of maintenance may drop. In such cases an epidemic of water-related disease could be more disastrous in a town than in the countryside.

Finally, any large water project should include fisheries and forestry, and also the conservation of nature, as environmental activities ancillary to the primary objective. Each of them carries weight in the prediction of vector-borne diseases. One might add the philosophical point that human evolution, as well as that of other animals and plants, has always progressed by diversity, not uniformity. Therefore, human settlements associated with water projects are more likely to prosper if they include families concerned in ancillary occupations, and are not limited to the narrower outlook of the primary objective of the project.

METHODS OF FORECASTING THE VECTOR-BORNE DISEASE IMPLICATIONS IN THE DEVELOPMENT OF THE DIFFERENT TYPES OF WATER RESOURCES PROJECTS: VECTOR ASPECTS

by

P.M. Wijeyaratne

INTRODUCTION

Health, as defined by the World Health Organization, is not merely the absence of disease, but a state of complete physical, mental and social well-being of human beings and their communities. It depends on the proper balance between many basic components of human needs and human behaviour. This implies the consideration of ecology in its broadest sense, and water can be considered to be a central pivot around which all other factors revolve. Water-related and water-borne diseases have always taken a major toll on human lives, and vector-borne diseases are no exception.They still represent a constant and serious risk to the major part of the world's population. Recent proliferations of the development of various types of water resources in endemic countries appear to be directly or indirectly associated with the concurrent proliferation of a number of vector-borne diseases - notably malaria, schistosomiasis and onchocerciasis, and perhaps others.

The purpose of this paper is to examine the ecological changes that are likely to take place in an area with the development of a water resource and, more importantly, to assess the possibilities of forecasting the changes likely to take place in vector populations.

VECTORS AND DISEASES

This paper considers:

- *Culex quinquefasciatus* , which breeds in organically polluted water and is associated with bancroftian filariasis and arbovirus transmission;
- *Culex tritaeniorhynchus* , the rice field breeding mosquito known to be a vector of Japanese encephalitis;
- *Aedes aegypti* , the container breeding mosquito vector of the dengue virus group, and of the yellow fever virus in urban situations;
- *Aedes simpsoni* , breeding in banana, Colocasia and pineapple leaf axils and incriminated in the sylvatic yellow fever cycle;

At the time of preparation of the paper Dr Wijeyaratne worked for the Department of Community Medicine, Ahmadu Bello University, Zaria, Nigeria; his present position is Program Officer, Health Sciences Division, International Development Research Centre, Ottawa, Canada

- *Aedes africanus* , a tree hole breeding mosquito species, also incriminated in the sylvatic yellow fever cycle;

- *Mansonia* spp. , breeding in ponds with *Salvinia* spp., *Eichhornia crassipes*, etc., attached to their roots and associated with Brugian filariasis, and Spondweni arbovirus transmission;

- *Anopheles* ssp. , breeding mostly in clean still or slowly moving water with or without vegetation and shade and responsible for the transmission of malaria and bancroftian filariasis, as well as Chikungunya arbovirus;

- *Cyclops* , the tiny fresh water crustacean that thrives in ponds and is the intermediate host of dracunculiasis (Guinea worm infection);

- *Glossina* ssp. , the tsetse fly, generally associated with light forest type vegetation zones in Africa: certain species (*G. palpalis*) are found in riverine areas. They are responsible for the transmission of African trypanosomiasis in man (sleeping sickness) and cattle (nagana);

- *Simulium* ssp. , the black fly, breeding in fast flowing clear waters attached to any suitable substratum and the vector of onchocerciasis; capable of long distance migration;

- Aquatic snails: bulinids - *Schistosoma haematobium* transmission; planorbids - *S. mansoni* transmission; and *Oncomelania* , the genus of amphibious species - *S. japonicum* transmission. All these are aquatic snails found in still or very slow-moving waters and often associated with certain types of aquatic vegetation and muddy soil; capable of aestivation.

The detailed ecology of most of these vectors is well documented and will not be discussed in this paper.

DIFFERENT METHODOLOGIES OF FORECASTING

The model suggested in this paper gives a basis for quantitatively estimating parameters that influence the populations of vectors, in particular basic life-table characteristics such as fecundity, mortality and survival, as well as migration (emigration and immigration). The main biological factor in population increase is fecundity; and the main ecological factor is immigration. Similarly, mortality or dispersal (emigration) will decrease the vector populations under discussion.

The sets of parameters required for a method of forecasting is fixed, but different methodologies will require different parameters. The nature and type of the parameters that are needed for a particular method can be arrived at on the basis of the system outlined below.

Several methods of forecasting have been documented. Some of them are promising for forecasting vector population dynamics such as in the development of a water resource. The predictive population method of life budget, for instance, is very pertinent to this problem. The model requires estimates of age specific mortality rates. These parameters may be estimated by suitable logically deduced relationships between the factors outlined in the model suggested and

suitable logically deduced relationships between the factors outlined in the model suggested and the actual mortality observed. If logical deduction is difficult in a given situation, then pertinent field data may be collected to ascertain the quantitative relationship between the factor envisaged and the mortality and migration of the vector concerned. For instance, increased water velocity affecting snail mortality can be measured to indicate the change in the snail population. Ages of snails could be determined by standard available methods, e.g., shell base-to-apex height measurements for bulinids, shell disk diameter of planorbids or the spine height of *Oncomelania* , as easily determined using a vernier calipers scale. Age composition, however, is subjected to change - this change being affected by environmental effects of water resource development, for example dam construction. Changes in the age composition could also be determined logically (by deduction) or statistically (by active field measurements).

Similarly, intrinsic rate models as developed by Hughes (1962) or the Lewis-Leslie matrices method can be employed; both have advantages and disadvantages as reviewed by Southwood (1978). Gilbert and Hughes (1971) investigated the value of stochastic as opposed to the more simple deterministic models and concluded that they do not provide significantly more insight. Which particular method is most suitable for the given purpose and under certain field conditions for forecasting purposes can be decided only on an individual basis and given the appropriate type of data.

THE FORECASTING MODEL

For convenience of discussion an attempt is made here to present a simple dioristic type model (Southwood, 1978) for the two dynamic stages of the development of a water resource scheme in a given area: the construction stage and operational stage. In this case a generalised conceptual model is outlined for the study of determinants of the increases and reductions in disease vector populations as influenced by dam construction. The emphasis of the model is on the ability to predict any vector population changes that may take place.

The operational stage is divided into two logically distinguishable components -one with immediate and short term effects and the other with the expected long term effects. The hypothetical model assumes that:

- the area is a tropical one with seasonal rains of 4 months duration, generally high temperatures (23° - 33° C) and located inland, away from the coastal zone;
- a perennial stream is the water resource planned to be impounded;
- the development objective is a moderate-sized scheme for irrigated agriculture;
- all the listed vector species are prevalent in that general geo-climatic zone; and
- the listed vector-associated health conditions are either sporadically reported or documented in the surroundings or are endemic in the area.

Although the planning and design stage of any water resource development is the all-important point to initiate health-related preventive action, in this paper that stage is considered separately

The model itself will serve to be useful in at least three ways:

- to define the relationships under study;
- to facilitate consideration of the process in a logical, sequential and functional framework; and therefore
- to be able to make predictions about the changes likely to take place with various inputs.

This approach will eventually help to quantify and develop magnitudes of the various transfer functions in different sets of inputs and outputs, e.g., increasing the water velocity in an irrigation canal from 0.5m/sec to 2.0m/sec decreased the snail population by three quarters. The values of water velocity obtained here in relation to reduction of snail population size will be of immense help at the design stage of the canal in forecasting and therefore preventing build-up of snail populations in the canals.

The conceptual model is presented on pages 24, 25 and 26 in three components, identified for convenience as: model I - construction stage; model II - operational phase on the short term; model III - operational phase on the long term.

TYPE OF INFORMATION NEEDED

Specific entomological data

One of the most directly obtainable pieces of information on the influence of factor on the vector population concerns changes in population size. The ultimate aim, however, is to assess the impact of such changes on the transmission of pathogens to man. The dynamics of a vector population and its interaction with the pathogen and vertebrate host is a complex system with many variables. These variables have been manipulated in many ways into various models (Macdonald, 1973) so as to be able to forecast effects of natural changes and man-made interventions, including control of various parameters. The product of all the interacting factors that cause an arthropod to become infected with a given pathogen and to transmit it to its vertebrate host is termed vectorial capacity (WHO, 1972). This involves two sets of factors:

- certain intrinsic or physiological factors, and
- other factors which are influenced by the environment: such factors are population density, longevity, host selection, dispersal and flight range.

Population size is an important specific measure that is needed in the forecasting model described in this paper. Various methods of making relative and absolute estimates of vector populations were reviewed by a WHO scientific group (1972) as well as by Southwood (1978). For mosquitos, the mark-release-recapture method appears to have been used most frequently for both adult stages (Sheppard *et al* ., 1969) and also for larval assessment. A variety of sampling techniques for mosquito larval and adult population assessment have been developed and used widely in the field, as reviewed by WHO (1975). Their applicability to a given situation also depends on the type and training of the available personnel. For aquatic snail studies, the tech-

depends on the type and training of the available personnel. For aquatic snail studies, the techniques for population assessment are reviewed in the WHO monograph, ''Snail Control in the Prevention of Bilharziasis'', (WHO, 1965). The scoop net sampling method has been frequent method of choice by most workers and is very much applicable to dam type situations and surveys.

Apart from population size assessment, an entomological or malacological survey should obtain specific information on detailed ecological characteristics of the situation relevant to the breeding of the particular vector. A schistosomiasis intermediate host survey for bulinids and planorbids should, for instance, obtain information on:

- temperature conditions of the water;
- chemical composition of the water (pH, salinity, Ca^{++}, Mg^{++} content, etc.);
- aquatic vegetation (e.g. *Ceratophyllum* , *Potamogeton* are favourably associated);
- soil composition
- water velocity
- aestivation
- predators, parasites, pathogens of snails, etc.

For *Simulium* breeding, many factors in the breeding environment have been considered as useful indicators influencing their population size, e.g., altitude, water current, water temperature, pH, conductivity, salinity, water hardness, alkalinity, water colour, turbidity, 0_2 - BOD, and a host of specific chemical characteristics such as chlorides, sulphates, iron, copper, ammonia, total nitrogen, etc. Hence, such information should also be gathered during a survey. Detailed aspects of *Simulium* ecology are reported in Laird (1981) and WHO (1970).

Background information on planning aspects of the project

Entomological data should not be considered in strict separation; it can be expected that the information they provide will be most profitably used when tied in with a wide range of planning information such as:

- human population characteristics of the area, e.g., local economy, traditions, basic demography, etc.;
- environmental hygiene patterns in the area, e.g., housing, water, sanitation, etc.;
- bio-epidemiological aspects, e.g., health conditions and health services in the area, potential problems and priorities;
- climatological details, e.g., temperature, rainfall, etc.;

- topographical description, e.g., watershed, roads, villages;
- operational engineering information, e.g. hydrology, geology, etc.
- flora and fauna and agriculture and practices;

Specific engineering design factors

Just as important as acquiring the knowledge of the environment of the proposed project as indicated above, is a thorough entomological consideration of the various factors or phases of the project itself. This is crucial for the correlation with the bio-entomological information and was the basis for constructing the forecasting model proposed in this paper. Such specific engineering design factors are listed below:

- the chosen locality;
- the specific project design;
- proposed water system management practices;
- reservoir design, design details, e.g., deforestation, shore line, discharge structures, etc.;
- irrigation scheme designs, e.g., canals, sluices, farm practices, etc.;
- human settlement site selections, e.g., sanitation, recreation protection, etc.;
- environmental management practices, the management and incorporation of vector control procedures into the scheme;
- long-term public enlightenment programmes (health education) with community participation;
- Support of health care facilities - preventive and curative.

Information gathering methods and personnel

The desired type of information related to vectors, as indicated earlier, can be obtained by the pooling of information from various sources such as:

- local knowledge from the people;
- local health office or dispensary records on morbidity in the area;
- hospital records on morbidity;
- university organized studies in the area;

- prospective studies (longitudinal); or

- cross-sectional studies (point prevalence).

The latter two are surveys, and a pre-project entomological survey of the area would be most essential and has no valid substitute.

The accuracy and reliability of the pre-project entomological and ecological data is an essential pre-requisite for assessing and forecasting changes due to certain impositions such as various dam construction activities.

It is, therefore, very important that qualified, well trained personnel carries out the surveys. Entomologists, ecologists and public health engineers will need to work together along with locally recruited and trained assistants. If these assistants are indigenous from the general area it may be a tremendous boost for community participation and education aspects which should follow later on during theconstruction and operational phases. Most tropical and developing countries are now increasingly producing health auxiliaries to operate at various levels. These health auxiliaries can be trained and motivated to be able and reliable entomological assistants to work under supervision. They will not only participate in the pre-project surveys but also on follow-up studies which are best carried out continuously. The extent and scope of follow-up studies should be reviewed periodically, but a comprehensive post-project survey should also be carried out. The timing for such a survey will have to be determined for individual projects, considering the vectors, diseases and the magnitude of the project, among other criteria. An entomological surveillance scheme nevertheless is an essential component to be incorporated into the general maintenance and management programme of any large water resource development project in an endemic or potentially endemic area. This will ensure the careful and timely monitoring of any expected or unexpected changes taking place, so that appropriate corrective measures can be applied.

CONSTRUCTION STAGE

COMPONENTS	VECTOR POPULATION CHANGES: *Culex fatigans*	*Culex tritaeniorhynchus*	*Aedes aegypti*	*Mansonia* spp.	*Aedes simpsoni*	*Aedes africanus*	*Anopheles* spp.	*Cyclops* sp.	*Glossina* spp.	*Simulium damnosum* s.l.	*Bulinus* spp. *Biomphalaria* spp. *Oncomelania* spp.
A) Labour and population emigration/immigration, equipment movements and temporary housing (sanitation, introduction of new vector species, spread of vector species present)	+	0	+	0	0	0	+	0	+	+	0
B) Road construction and deforestation (earth movements and terrestrial vegetation clearance)	0	0	0	0	-	-	0	0	-	0	0
C) Excavation activities (creation of borrow pits, ponds with aquatic vegetation)	+	0	0	+	0	0	+	+	-	0	+
D) Stream/river stoppage or slowing (increased seepage, marshes and pools)	0	+	0	+	0	0	+	+	+	-	+
E) Faunal and floral movements (cattle, birds, other animal and plants; migration of new vector/intermediate host species)	+	0	0	+	+	+	+	0	+	0	+
F) Contamination and organic pollution	+	-	0	0	0	0	-	0	0	-	0
G) Reservoir, impoundment, spillway, irrigation/ drainage canal construction	0	+	0	+	0	0	+	0	0	0	0
H) Climatological (rainfall, temperature, wind disturbances)	0	0	0	0	0	0	0	0	-	-	-
<u>SUMMARY</u> Grossly disturbed and interfered ecosystem equilibrium and species balance	4+	+	+	4+	0	0	4+	2+	0	3-	2+
Some new or sporadic host-vector contact leading to infection	Bancroftian filariasis	Japanese encephalitis	Dengue, yellow fever	Brugian filariasis, arbovirus (Sponwendi)	Yellow fever	Yellow fever	Malaria, bancroftian filariasis, Chikungunya	Dracunculiasis	African trypanosomiasis	Onchocerciasis	Schistosomiasis ; fascioliasis - *S.haematobium* - *S.mansoni* - *S.japonicum*

OPERATIONAL PHASE - SHORT TERM EFFECTS (less than 5 years)

COMPONENTS	VECTOR POPULATION CHANGES										
	Culex fatigans	*Culex tritaeniorhynchus*	*Aedes aegypti*	*Mansonia* spp.	*Aedes simpsoni*	*Aedes africanus*	*Anopheles* spp.	*Cyclops* spp.	*Glossina* spp.	*Simulium damnosum* s.l.	*Bulinus* spp. - *Biomphalaria* spp. *Oncomelania* spp.
A) Increased water surface area	0	0	0	0	0	0	+	0	+	-	-
B) Raised water table in the vicinity	0	0	0	+	0	0	0	+	-	0	+
C) Upstream slowing of water current, shoreline and vegetation submergence	+	+	0	-	0	0	+	0	-	-	+
D) Increased seepage, formation of pools, ponds and swamps, particularly in old water courses	+	+	0	+	0	0	+	+	0	0	+
E) Beginning erosion in immediate area	0	0	0	0	0	0	+	0	0	+	-
F) Spillway/downstream canals - increased water flow, canals may be lined or unlined	-	-	0	-	0	0	-	-	-	+	-
G) Flooding of rice fields and other farm lands	+	+	0	+	0	0	+	+	0	+	+
H) Change in water characteristics: nutrients, sedimentation, microbial content, conductivity, temperature, etc.; also: wind and wave action	0	0	0	0	0	0	-	-	0	-	-
I) Succession of macro aquatic flora and fauna	+	+	0	+	+	+	+	+	0	0	+
J) Changed terrestrial vegetation, including cash crop or subsistence farming, reforestation	+	+	+	+	+	+	+	+	+	0	+
K) Changed terrestrial fauna, including rodents, livestock and birds; animal contamination of water	+	+	+	+	+	+	+	-	+	-	+
L) Beginning human settlements, associated activities; water storage habits, waste disposal, water contact at wells and damsites	+	0	+	0	+	0	+	+	-	0	+
M) Contamination, pollution and infection	+	0	0	0	0	0	-	-	0	-	+
<u>SUMMARY</u> Simplification of the habitat, increased area of ground water; raised water table	7+	5+	3+	4+	4+	3+	6+	2+	1-	2-	5+
Increased host-vector contact	Bancroftian filariasis	Japanese encephalitis	Dengue, yellow fever	Brugian filariasis, arbovirus (Sponwendi)	Yellow fever	Yellow fever	Malaria, bancroftian filariasis, chikungunya	Dracunculiasis	African trypanosomiasis	Onchocerciasis	Schistosomiasis - *S. haematobium* - *S. mansoni* - *S. japonicum* ; fascioliasis

OPERATIONAL PHASE - LONG TERM EFFECTS (more than 5 years)

COMPONENTS	VECTOR POPULATION CHANGES										
	Culex fatigans	Culex tritaeniorhynchus	Aedes aegypti	Mansonia spp.	Aedes simpsoni	Aedes africanus	Anopheles spp.	Cyclops sp.	Glossina spp.	Simulium damnosum	Bulinus spp. Biomphalaria spp. Oncomelania spp.
A) Filled reservoir, with slow water flow upstream, and high water levels over a long distance upstream	0	0	0	+	0	0	+	0	+	0	+
B) Fast, turbulent water over a long distance downstream; also in irrigation canals close to human habitations	-	-	0	-	0	0	-	-	-	+	-
C) Reservoir shore line may be: steep and rock-lined or cemented; shallow and unlined soft mud	0	0	0	+	0	0	+	0	+	-	+
D) Stabilization new topograpgy, including erosion and water characteristics; formation of permanent swamps due to seepage; stabilized climate	+	+	0	+	0	0	+	+	+	0	+
E) Succession aquatic micro and macroflora finished succession and reached equilibrium	0	+	0	+	0	0	+	+	+	+	+
F) Reforestation effected; terrestrial natural vegetation stabilized in density	+	+	+	+	+	+	+	0	+	+	0
G) Agro-ecosystem stable with the selected crops: sugar cane, rice, cotton, bananas, etc., and their inherent irrigation requirements	0	+	0	+	+	+	+	+	0	+	+
H) Faunal succession completed; balanced ecology vertebrates and invertebrates	0	-	0	-	0	0	-	0	0	0	0
I) Established domestic animals, livestock, rodents	+	+	+	+	+	+	+	0	+	+	+
J) Fishery development in impoundment	0	0	0	0	0	0	-	0	0	0	0
K) Proximal and distant perennial irrigation	+	+	0	+	+	+	+	0	+	+	+
L) Spillway, with either intermittent flushing and water level fluctuation, or perennial flow at high velocity	-	-	0	0	0	0	0	0	0	+	0
M) Human settlements in reservoir vicinity; pollution; intense water contact, water wells deforestation	+	0	+	-	+	-	0	+	-	0	+
SUMMARY New ecosystem with central water dominance and established habits and practices	2+	3+	3+	4+	5+	3+	3+	3+	4+	4+	5+
Prolonged vector contact leading to multiple infections	Bancroftian filariasis	Japanese encephalitis	Dengue, yellow fever	Brugian filariasis, arbovirus (Sponwendi)	Yellow fever	Yellow fever	Malaria, bancroftian filariasis, Chikungunya	Dracunculiasis	African trypanosomiasis	Onchocerciasis	Schistosomiasis; fascioliasis - S.haematobium - S.mansoni - S.japonicum

VECTOR AND WATER BORNE DISEASES ASSOCIATED WITH DEVELOPMENT PROJECTS

by

Jacobo Finkelman and
A. A. Arata

INTRODUCTION

It is estimated that only about one-seventh of the world's arable land is at present under irrigation, yet this area accounts for more than one-third of the total value of crop production. To increase the desired doubling of food output in developing countries before the year 2000, at least half of the increase will have to come from irrigated land. This will call for further enormous investments in irrigation over the next two decades; one estimate is for approximately US$ 230,000 million at 1975 prices (WHO, 1982).

This paper is inspired by resolution WHA35.17 (1982, see: page 39) which pledges WHO's total commitment .. [...] .. to minimize the risks to the health of populations in relation to development projects, especially those associated with water resources development. All water-development projects are based on specific decisions to accomplish certain objectives: generation of hydroelectric power, irrigation for agricultural development, drinking water supply, flood control, recreation, or a combination of these objectives. In general, these projects are planned with the ultimate objective of creating social and economic benefits.

All too often, however, development projects do not include public health or potential disease problems in their initial costings. It is also not certain that the populations directly affected by the project are the ones that benefit from the activity. Specifically, what are the composite risks and benefits to the health of the population in the area affected, and the changes that occur as the project develops? From this point of view, we must consider the population in question as well as the specific diseases of the area. Whereas each disease can be measured by its individual epidemiological parameters (e.g., incidence, morbidity, disability, etc.) the population should be evaluated in relation to overall health status at various times in a changing environmental situation.

Decisions on financial investments in health care, both preventive and curative, should be based in broad terms and over longer periods than are usually available for analyses of effects of projects. It should be recognized that change may not always be deleterious and that methods for analysis of these changes require improvement.

Dr J. Finkelman is the Director of the WHO/PAHO Centre for Human Ecology and Health, Metepec, Mexico. At the time of preparation of the paper, Dr Arata was also attached to this Centre; his present position is Senior technical Officer, Vector Biology and Control Project, Arlington, USA

VECTOR- AND WATER-BORNE DISEASES ASSOCIATED WITH WATER RESOURCE PROJECTS

At the first meeting of PEEM (Geneva, 1981) the Panel recognized 37 diseases or groups of diseases that were water-related. Attention was given to the more important vector-borne diseases: malaria, schistosomiasis, the filariases including onchocerciasis, as well as the arboviral diseases. The prevalence of these differs greatly throughout the developing world and it is not easy to compare the problems as they exist in the various regions. The present discussion will focus largely on the situation in the Americas.

Malaria

The global distribution of malaria is shown in figure 1, and table 1 (adopted from PAHO, 1982) shows that in the Americas there has been an increase in the number of cases over the past decade. As shown by susceptibility tests, the chloroquine resistant *P. falciparum* strains are gradually sprading in the region. The obstacles to the success of the malaria eradication programme in the Americas have been listed, as follows:

- Technical problems: associated with the development of insecticide resistance or behavioural changes in anopheline populations.

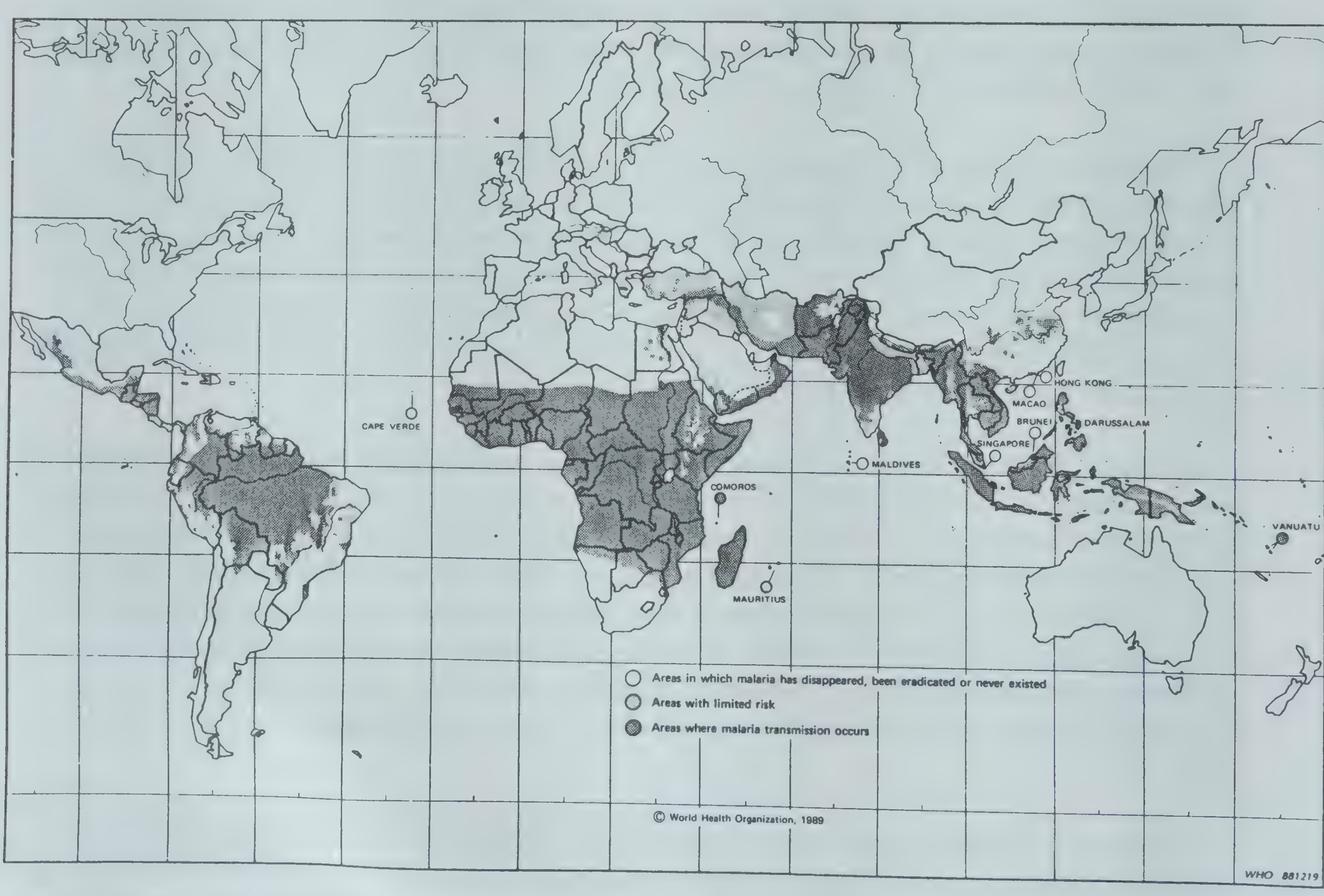


Figure 1: the epidemiological assessment of the status of malaria, 1987
Source: WHO, Malaria Action Programme, 1989

- Economics related to development: all the countries of the Americas are actively promoting economic development projects. Agricultural settlement of new lands and the construction of highways, hydroelectric plants, dams and the like always bring immigrants and workers to areas where living conditions are precarious. In the past 20 years, the geographic extension of the malarious area has increased as and when new land areas have been opened up to development projects and resettlement.

- Budgetary problems: the funds assigned by governments to malaria control programmes have progressively increased in the past 20 years. This increase has, however, been offset by the rising cost of personnel, supplies, equipment, and means of transport. In addition, in some countries the appearance of technical problems such as vector resistance to DDT and other insecticides and parasite resistance to drugs has made it necessary to apply different or supplementary measures that are much more expensive. Furthermore, the increase in the malarious areas, new population settlements, and frequent outbreaks of the disease among immigrants are problems whose solution calls for a large amount of funds which, as a rule, are not easy to obtain. In many countries, the present level of financing is barely sufficient to protect the areas in which malaria has been eradicated and, at the same time, to solve problems in areas where transmission persists. Because of financial constraints, many countries plan their activities by order of priority or use their resources solely to prevent epidemic outbreaks or to deal with emergency situations.

In table 1 it can be seen that the total number of reported malaria cases in the Americas (1980) was of the order of 550 000. Although the situation is better than in Africa, where the number of children's deaths due to malaria is estimated at about one million annually, it is far from encouraging, in view of the problems that have developed in the past decade.

TABLE 1. REPORTED CASES OF MALARIA IN THE AMERICAS (IN THOUSANDS) WITH PERCENTAGE CHANGE BY SUBREGION, 1970-1982

Subregion	1970	1980	1982	Percentage change 1970-1982
Northern America	3.0	2.7	-	-13%*
Caribbean+	10.9	13.1	70.0	544%
Continental Middle America	186.1	251.3	288.0	55%
Temperate South America	0.08	0.3	-	306%*
Tropical South America++	144.7	270.6	346.3	139%

*percentage change 1970-1980
+Haiti reported 65 400 cases in 1982
++Large increases in the Brazilian Amazon region

TABLE 1 (CONTINUED). SELECTED EXAMPLES: REPORTED CASES (IN THOUSANDS) AND PERCENTAGE INCREASE, 1977-1982

	1977	1978	1979	1980	1982	Increase
El Salvador	32.2	52.5	75.6	95.8	86.2	169%
Guatemala	34.9	59.8	70.6	62.7	77.4	122%
Mexico	18.9	19.1	21.0	25.7	50.0	165%
Nicaragua	11.6	10.6	18.4	22.0	15.6	34%
Honduras	39.4	34.6	25.3	42.8	57.5	46%
Brazil	104.4	121.6	147.6	176.2	221.9	113%

Sources: data for 1970-1980 from PAHO, 1982; data for 1982 from WHO, 1984

Schistosomiasis

The global distribution pattern of *Schistosoma mansoni* , the only parasite species occurring in the Americas, is shown in figure 2. As schistosomiasis is not a reportable disease, estimates of prevalence are of dubious value. Furthermore, the severity or intensity of infection of *S. mansoni* in the Americas has only been well studied in certain locations (such as Saint Lucia and parts of Brazil).

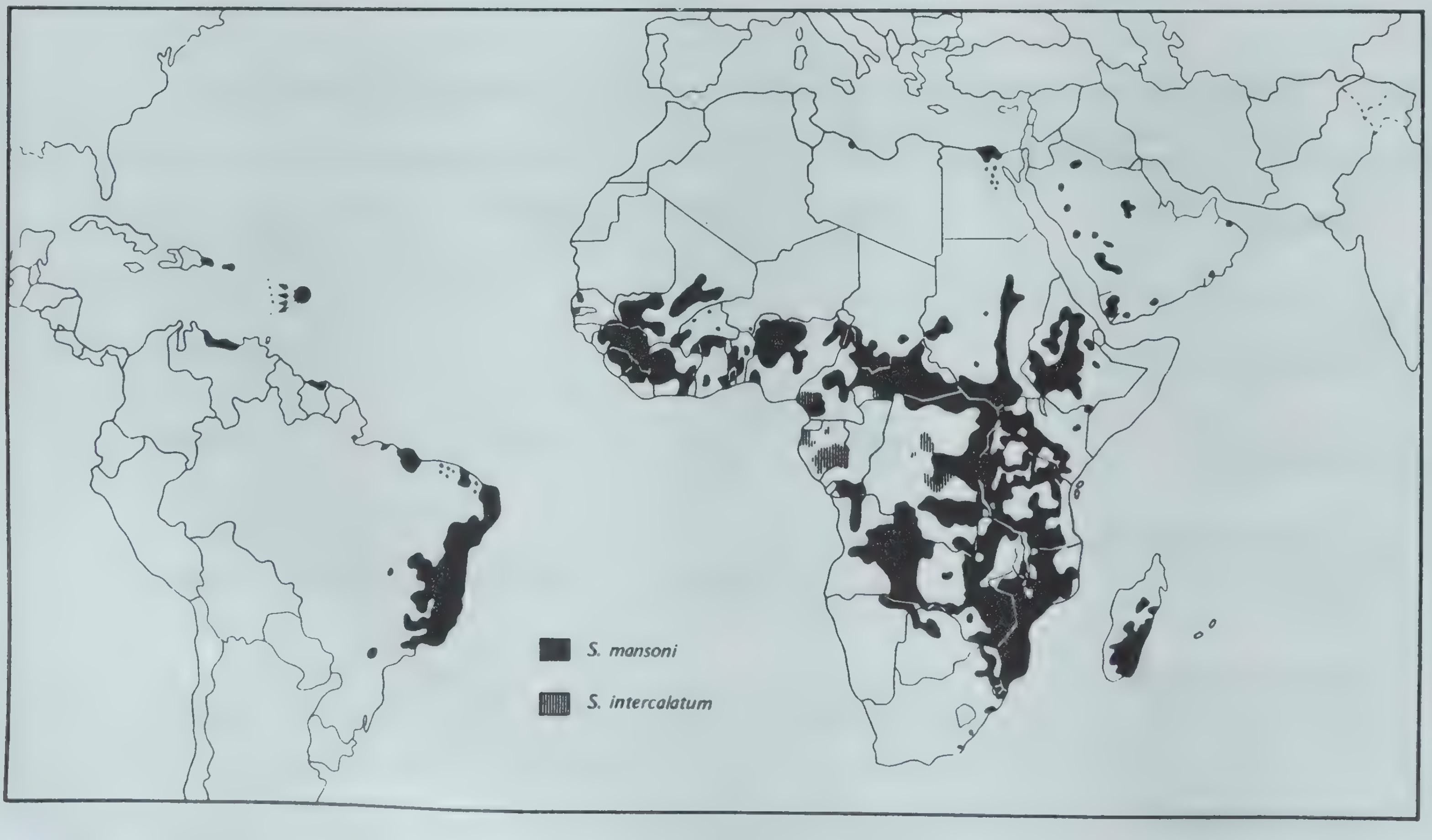


Figure 2: global distriburion of schistosomiasis due to *S. mansoni* and *S. intercalatum* , 1985
Source: WHO, 1987

The following statement is taken from Health Conditions in the Americas, 1977-1980 (PAHO, 1982):

''Schistosomiasis ranks second only to malaria as the major parasitic disease of the tropics. Precise information on the prevalence of the disease in the Region was not available. [reported rates per 100,000 popualtion are given in a table accompanying the statement; some examples: Surinam: 437 in 1978; 385 in 1980; Saint Lucia: 133 in 1978; 33 in 1980; no figures given from Venezuela or Brazil in 1979 and 1980 - authors]. The cases notified from Cuba and Guatemala probably represented imported cases since no local transmission was reported in either country. The disease declined in Puerto Rico and Saint Lucia, and a few cases were reported recently from the Caribbean island of Montserrat.''

An extensive intervention research programme for schistosomiasis control has been underway in Brazil and Surinam with support from the UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases (TDR). A recent progress report (WHO,1983) summarizes the results until 1983 in Brazil. The following excerpts are important in the context of the present paper:

(a) Of 771,194 stool examinations completed, 20.4% were positive, which indicates more than 1,150,000 cases of schistosomiasis in the population [of northeastern Brazil] surveyed so far.

(b) After treatment [chemotherapy with oxamniquine] of more than 1.5 million persons, the experience accumulated and the broad receptivity of the target population have demonstrated that the strategy can be continued without major alterations.

[Authors' note: examples of reduction following two treatment cycles were as follows:

Rio Grande do Norte	15.7% to 3.4% to 2.5%
Ceará Mirim	27.2% to 9.4% to 7.9%
Bahía Formosa	39.9% to 13.9% to 13.7%
Pureza	53.4% to 11.9% to 8.9%]

(c) Generally speaking it was found that, after geographical reconnaisance, chemotherapy progressed more rapidly than the other control measures proposed by the PECE (Special Programme for Control of Schistosomiasis) such as snail control and sanitation.

(d) It is therefore of the highest importance that there be a coordination of control measures such as ecological modification (sanitation, removal of snail breeding sites through engineering modification or application of molluscicides) with measures to reduce human infection (chemotherapy) or to modify the affected populations (through education, safe recreational facilities). The application of these intervention methods should be promoted and, whenever possible, precede chemotherapy.

Onchocerciasis

The overwhelming preponderance of onchocerciasis is of course in Africa and the studies under the auspices of the Onchocerciasis Control Programme over the past years have well described the epidemiology and control measures.

The known distribution in the Americas (figure 3) is diffuse and possibly other foci exist as yet undiscovered (WHO, 1976). In Mexico and Guatemala where *Simulium ochraceum* is the vector, infections occur mainly in the coffee-growing areas. The majority of the infections are seen in males working in the coffee plantations and exposed during the peak biting times of the day.

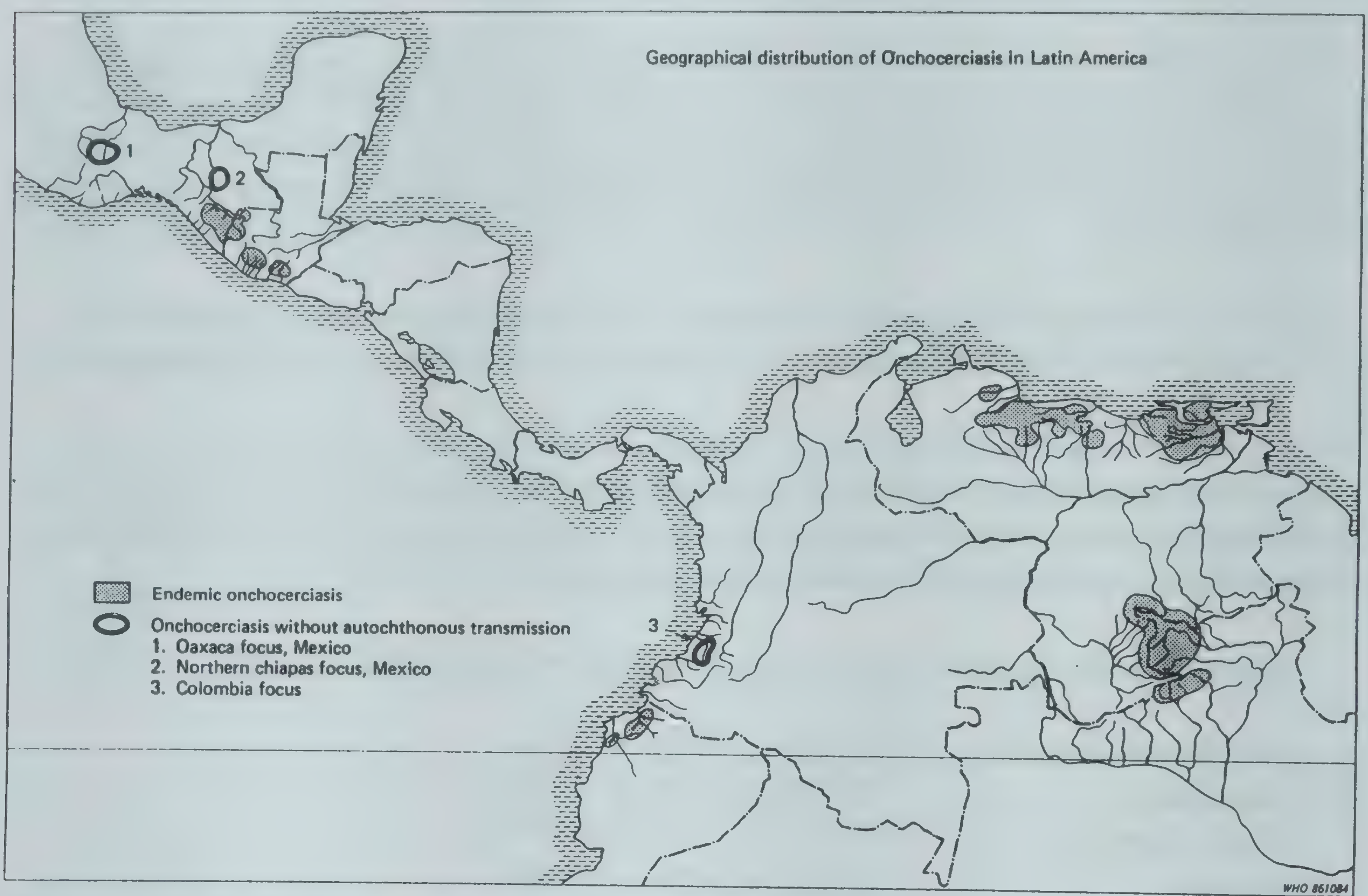


Figure 3: geographical distribution of onchocerciasis in the Americas
Source: WHO, 1985

Frequency of nodules is low in those infected in Colombia (23%), as compared to nearly 100% in West Africa, and the vectors are less efficient.

In Guatemalan *S. ochraceum* , a relatively much smaller portion (0.3%-7%) of the microfilariae ingested are successful in penetrating the fly's haemocoele as compared to 15-44% in West African forest *S. damnosum* .

The species complexes of *S. amazonicum* and *S. metallicum* in the Americas are not well known although they are now being studied. The reporting of the disease is poor, and most foci, and the intensity of infection, are only known from specific studies.

The foci known at present nevertheless do provide a rough guide for future surveillance where development projects are anticipated. This is perhaps especially true in the Amazon basin area where great economic development is anticipated.

Other vector-borne diseases

Information on the distribution and prevalence of bancroftian filariasis is not reported on a regular basis by the countries of the American Region, and most information available originates from specific local studies.

Problems related to the various encephalitides are also poorly known but sporadic outbreaks of Venezuelan Equine Encephalitis (VEE) and Eastern Equine Encephalitis (EEE) cause severe economic losses especially in those countries where horses are important in agricultural areas.

Yellow fever, although not normally associated with large bodies of water, is related to adjacent communities and continues to be a problem in the American Region.There were 217 reported cases in 1969-1972, 654 reported cases in 1977-1980 and 489 reported cases in 1981-1982. The increase may have been due to increased migration and settling in jungle areas. On the whole the geographical area affected by yellow fever has continued to contract over the past ten years.

Dengue is of particular concern in the Caribbean island states and the countries bordering the Caribbean basin, especially since the appearance of dengue haemorrhagic fever cases in the Americas. Prior to 1977, dengue virus serotype 1 did not circulate in the Caribbean, and an epidemic beginning in Jamaica that year spread widely. Serotype 2 was subsequently associated with haemorrhagic fever cases in Cuba in 1981 (Guzman *et al* ., 1984). Serotypes isolated in 1982 and 1983 include: serotypes 1 and 4 in Barbados and Surinam, serotypes 1,2 and 4 in Trinidad and Tobago, and serotype 2 in San Vincente. Serotype 4 is encountered most frequently. Incomplete numbers of regional cases (from countries providing information, as dengue reporting is not obligatory) are as follows:

1977	500 000 cases
1978	125 000 cases
1979	42 000 cases
1980	32 600 cases
1981	350 000 cases*

* in 1981, a total of 344,203 cases of dengue were reported in Cuba (Guzman *et al* ., 1984).

To our knowledge the spread of dengue has not been directly linked to water resource development projects per se, but populations of the vector, *Aedes aegypti* , are certainly influenced by settlement patterns in densely populated tropical areas where there is little distinction between rural-agricultural practices and associated human populations in small urban communities.

EPIDEMIOLOGICAL CONSIDERATIONS IN CHANGING ENVIRONMENTS

Hazard-risk

In the Americas, as in most other regions of the world, it is not known how many water-development projects have been started or are under consideration. It is knownthat these projects will produce changes in health patterns, but these need not all be negative. Furthermore, the

deterioration of a single disease pattern or conditionmay not be indicative of the total health picture of the population, and changes in health status may be temporary and easily improved.

Thus, in examining a certain class of diseases (e.g., vector-borne diseases) the population at risk must be identified, and a distinction made between the terms hazard and risk. Hazards, in this connotation, are threats to human health: i.e., in a given zone, malaria, schistosomiasis, or onchocerciasis may present a hazard. Risks are quantitative measures of hazard consequences that can be expressed as conditional probabilities of experiencing harm. Thus, malaria or another vector-borne disease may be a hazard in a given locality, but the long-term risk of contracting the disease and suffering its ill effects is only a certain percentage ofthe risk of all the other diseases or disabilities from which the population might suffer in the same area during the same period. Then too, hazards cannot be classified generically but should be conditioned by severity in a given locality (e.g., *P. vivax* infections versus infections by *P. falciparum* in a drug-resistant area).

In the final section of this paper, a scheme will be presented for forecasting the health prospects of affected populations over time. This is, of course, complicated by many factors, not the least of which is the nature and degree of direct interventions made to assist the population and the timing of such interventions.

Population, disease and project interrelationships

The relationships between the categories of populations, the diseases and the types of projects is shown in figure 4.

(a) The people. As the human population is the target of our study we must, above all, be able to characterize it. We must know its history, its culture and its mode of living, including agricultural practices, socio-economic and educational levels, movement patterns, capability and willingness to change, etc. We must of course know its initial health pattern: endemic diseases (types, rates, severity), nutritional level, and, if possible, indicators such as life expectancy, and infant and maternal mortality. Such base-line data must also extend to the other populations that may enter the affected area

(b) Type of project. Here a distinction must be made between projects by purpose and extent, and the potential to intervene from the health standpoint must be considered. It is presumed that projects organized at national or international levels are better prepared, and funded, to treat the health aspects than are local projects. The type of project will also strongly influence the movement of the population, either by displacement from, or migration to, the affected area.

Irrigation projects are often local, generally small, and frequently provide little provision for studies related to the health of the population. Larger projects, especially hydro-electric dams and large-scale irrigation projects are frequently politically and economically motivated beyond a level at which the local health resources are able to cope.

The WHO/PAHO Center for Human Ecology Health has been asked to work in about ten projects, all of them large. The requests have concerned all aspects from conservation, fisheries, erosion problems, movements of people (planned or unplanned) and health. Too frequently, however, the frame-work for health services is not, or poorly, defined or funded.

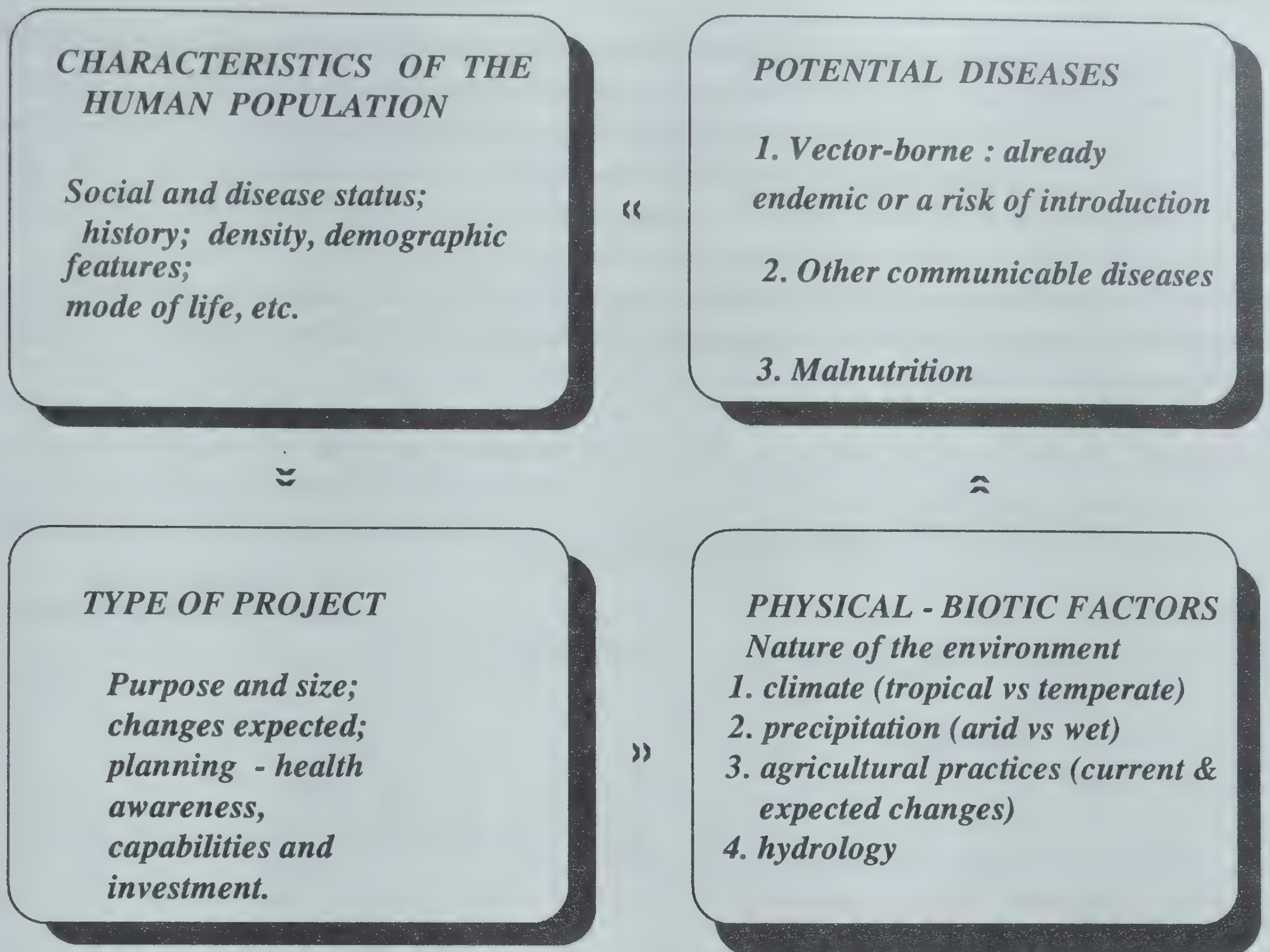


Figure 4. Relationships between the four variable components of a water resource development project. Change in one component will affect the status of all the others.

(c) Physical - biotic environment. The general setting of the project will directly determine the potential for increase or introduction of vector-borne disease and these aspects are discussed in the paper by E. Barton Worthington (pages 9-16). Other factors must also be considered: tropical areas will change at rates different from those in temperate zones; agricultural changes (perhaps shifting from subsistance farming to intensive cultivation of cash crops) may result in the introduction or intensification of pesticide usage with resulting problems of insecticide resistance in disease vectors; or, development of fisheries may help improve nutritional levels. One important factor is the establishment of a balance between the human population and the carrying capacity of the land in its modified form. The carrying capacity is a basic measure in ecology, referring to the number of animals and humans a given biota can support. Another important consideration is topography and the movement of people from highlands to lowlands and vice versa. Tropical zones are often mosaic in vegetational structure and indigenous people highly adapted to certain zones and their products. Dry tropics will differ greatly from wet tropics, etc.

(d) Disease potential. The disease potential is, of course, intimately related to the points mentioned above, but must be considered by area to determine hazard and risk. The hazards are those health problems that may be faced locally, independent of the scale of the proposed project. A sample matrix is shown in figure 5. Obviously, such a matrix must be adapted to the area, the project type, the people involved and their capacity to cope with change.

(e) Time. In figure 6 we show a proposed relationship between knowledge and action. The measures of health should change as the specific risks become more apparent. Objectives and methods of surveillance must be adapted to the disease potential in a given area. They should not be restricted to identification of pathology by given agents, but should employ and develop measures of general health status with a view to measuring change (positive or negative) over time. The means for future evaluation must be incorporated in the project design. There is clearly a need for development of appropriate methodologies oriented both at qualitative and quantitative techniques. Whatever the level of sophistication, the need for establishing continuity and standards is essential.

POPULATIONS	HEALTH MEASURES AIMED AT: VECTOR-BORNE DISEASES					OTHER DISEASES					GENERAL SOCIO-ECONOMIC IMPROVEMENTS			
	Malaria	Schistosomiasis	Filariasis	Arboviral diseases	Others	Diarrhoeal diseases	Nutritional disorders	Parasitoses	Accidents	Sexually transmitted diseases	Education	Housing	Infrastructure	Employment
Original residents														
Construction workers														
Spontaneous migrants														
Downstream residents affected by hydrological change														
Planned settlers														
Migrant populations (f.i., seasonal)														
Adjacent populations														

Figure 5. Provisional matrix for the study and assessment of the impact on public health of water resource development projects, for a specific phase of a given project.

CONCEPT OF HEALTH IN A CHANGING ENVIRONMENT OR RISK EVALUATION

There are several ways in which change can be measured, ranging from observational to predictive . In a changing environment, there is a range of parameters, from simple ones that can be used to measure the status of single diseases (e.g. malaria, diarrhoeal diseases or measles), to complex indicators of the level of health and well-being of the population as an entity. Three ways of measuring change are:

- **Observational.** Too frequently, environmental changes have been introduced without de tailed studies on the health of the population affected. Ex-post observations are,in effect, anecdotal.

● **Numerical**. This approach is a straight-forward statistical evaluation, following a planned protocol of applying epidemiological techniques, of the potential of certain specific diseases (such as the vector-borne diseases) to increase or decline in a given area over a certain period of time. The resultant data are statistically treated, followed by remedial action if required and the critical problem identified.

● **Prospective**. This approach will consider overall health gains or losses of the development project. It is a more comprehensive approach, implying greater complexity, and it requires the development of proper techniques to measure the various facets. The proper indices, in addition to the epidemiological (and, in the case of vector-borne diseases, entomological) ones, should include evaluation of existing and potential health services, rates of other communicable diseases (e.g., tuberculosis, parasitoses and diarrhoeal diseases), nutritional levels, life expectancy, maternal and infant mortality, education, social well-being, perceptions of health and welfare, etc.

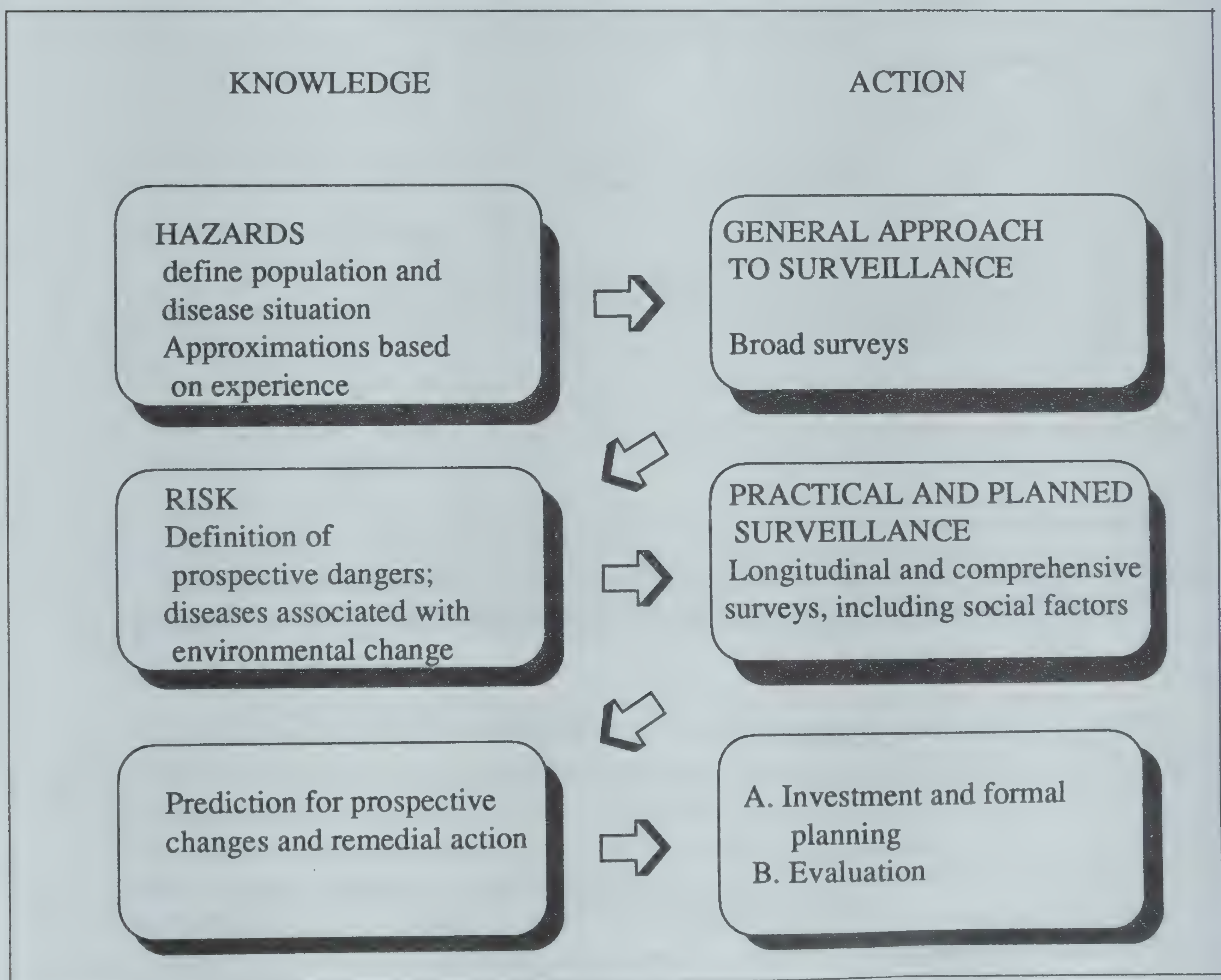


Figure 6. The relationship between knowledge and action in the consideration of health in the planning of a water resource development project.

This approach should also lead to prediction (forecasting) and intervention: these are intrinsically linked as there is no value in predicting if intervention is not envisaged. At this stage consideration should be given to cost/benefit analysis and forms of simulation modelling, e.g.,

the relative value of investment intervention in health at early stages of project development as opposed to subsequently (figure 7). This approach is an essential component of effective planning: at first results will be tentative, but accuracy should increase with repeated trials.

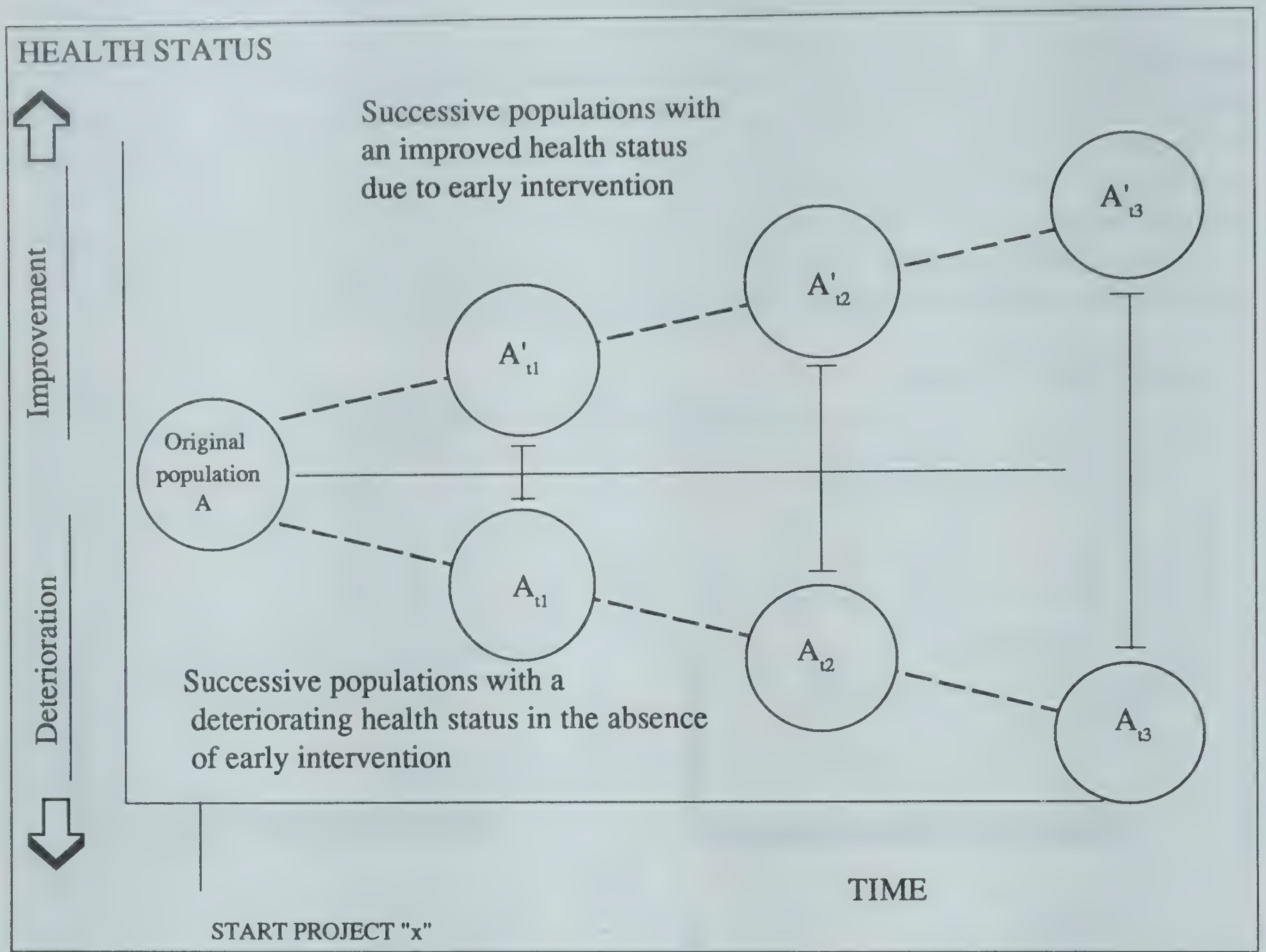


Figure 7. A growing discrepancy in the health status of populations with and without early health interventions as part of project development indicates the cost-effectiveness early interventions.

Unfortunately, in many projects little provision is made for health in the initial planning stages. Any economic input, small as it may be, will, however, be well reimbursed if it comes at an early stage. As we mentioned above the health or disease analysis must be comprehensive, and not focus only on one category or group of diseases. When a certain problem (e.g., enhanced mosquito breeding in an arid zone) is deemed of major concern, a team of health specialists should be organized to look into the problem. The conclusion of such a health impact assessment may be that it is cost-effective to invest in engineering measures for the prevention of vector-borne disease problems in a given project. Under different conditions, on the other hand, the team may find that financial resources are better spent on diarrhoeal disease control or social services such as housing, education and the like.

WORLD HEALTH ASSEMBLY RESOLUTION

THIRTY-FIFTH WORLD HEALTH ASSEMBLY

WHA35.17

14 May 1982

COLLABORATION WITH THE UNITED NATIONS SYSTEM - GENERAL MATTERS

Health implications of development schemes

The Thirty-fifth World Health Assembly,

Recalling resolution WHA17.20 on the importance of paying special attention to the health implications of large-scale socioeconomic development schemes;

Recalling further resolution WHA18.45 on the same issue;

Noting that many development projects carry major potential health hazards and dangers to the environment; that frequently insufficient resources are made available and/or applied in the planning and implementation of development projects to assess these hazards and to prevent their occurrence;

Noting further that, on occasions in the past, the health of populations and the environment have deteriorated as a result of development projects especially those associated with water resources development projects;

1. PLEDGES WHO's total commitment to work with Member States, international and national agencies and financial institutions to incorporate the necessary preventive measures into development projects to minimize the risks to the health of populations and the environment;

2. URGES Member States, national and international agencies and financial institutions, in the planning and implementation of development projects, especially those involving water resources development projects;

(1) to analyse in detail the possible health hazards and environmental dangers of existing and proposed development projects;

(2) to incorporate into project plans and their implementation adequate measures to prevent, to the greatest extent possible, the occurrence of health and environmental hazards;

(3) to make adequate provisions for the implementation of the necessary preventive measures in the financing of the relevant development projects;

3. APPEALS to donor countries and relevant financial institutions to assist developing countries in the implementation of the resolution.

Thirteenth plenary meeting, 14 May 1982
A35/VR/13

REFERENCES

P.M. Wijeyaratne

Hughes, R.D., 1962. A method for estimating the effects of mortality on aphid populations, *J. Animal Ecology, 31*: 389-396.

Gilbert, N. and Hughes, R.D., 1971. A model of an aphid population - three adventures, *J. Animal Ecology 40*: 525-534.

Laird, M., 1981. *Black Flies*, Academic Press, London.

Macdonald, G., 1973. *Dynamics of Tropical Disease*, by W.J. Bruce-Chwatt and V.J. Glanville (eds.), Oxford University Press, Oxford.

Sheppard, P.M., Macdonald, W.W., Tonn R.J. and Grab, B., 1969. The dynamics of an adult population of *Aedes aegypti* in relation to dengue haemorrhagic fever in Bangkok. *J. Animal Ecology 38*: 661-702.

Southwood, T.R.E., 1978. *Ecological methods with particular reference to the study of insect populations*, 2nd ed., rev. London, Chapman & Hall, 1978. 524 p.

World Health Organization, 1965. Snail Control in the Prevention of Bilharziasis, *WHO monograph series no. 50*, 247 p., Geneva.

World Health Organization, 1972. Vector Ecology. Report of a WHO Scientific Group, *Technical Report Series No. 501.*, Geneva.

World Health Organization, 1974. Manual on practical entomology in malaria, *WHO offset publication no. 1*, Geneva.

World Health Organization, 1976. Epidemiology of Onchocerciasis. Report of a WHO Expert Committee, *Technical Report Series no. 597*, Geneva.

World Health Organization, 1980. Environmental Management for Vector Control. Fourth report of the WHO Expert Committee on Vector Biology and Control, *Technical Report Series no. 649*, Geneva.

World Health Organization and Centre National de la Recherche Scientifique, 1988. *Atlas of the global distribution of schistosomiasis*, Presses universitaires de Bordeaux.

Finkelman and Arata

Guzman, M.G. et al., 1984. A study of fatal hemorrhagic dengue cases in Cuba, 1981, *Bull. Pan Am. Hlth.Org. 18(3)*: 213-220.

Pan American Health Organization, 1982. *Health Conditions in the Americas*, PAHO, Washington.

World Health Organization, 1976. Epidemiology of onchocerciasis, Report of a WHO Expert Committee, *Technical Report Series 597*, Geneva.

Additional References

Asian Development Bank, 1986, *Environmental Planning and Management*, proceedings of a regional symposium on environmental and natural resources planning (Manila, 19-21 February 1986), ADB, Manila.

Birley, M.H. and Thomas, H.M., 1986. Review of Expert Systems, *Parasitology Today 2 (3)*: 87.

Birley, M.H., 1987. *Guidelines for Forecasting the Vector-borne Disease Implications in the Development of a Water Resource Project*, preliminary draft version, document VBC/86.3, World Health Organization, Geneva.

Biswas, A.K. and Geping, Q. (eds.) 1987. Environmental Impact Assessment for Developing Countries, *Natural Resources and the Environment Series no. 19,* Tycooly Publishing, London.

Canter, L.W., 1985. *Environmental Impact of Water Resources Projects*, Lewis Publishers Inc., Chelsea, Michican, USA.

Food and Agriculture Organization of the United Nations, 1987. Consultation on Irrigation in Africa, FAO *Irrigation and Drainage Paper no. 42*, Rome.

Food and Agriculture Organization of the United Nations, 1987. *Effects of Agricultural Development on Vector-borne Diseases*, document AGL/MISC/87/12, Rome.

Gabinand, A., 1987. Ecological mapping to support mosquito control on the French Mediterranean Coast, *Parasitology Today 3 (10)*: 317-319.

Goldsmith, E. and Hildyard, N., 1984. *The Social and Environmental Effects of Large Dams* (Vols. I-III), Wadebridge Ecological Centre, Worthyvale Manor, Camelford, Cornwall, UK.

Goodland, R.J.A., Watson, C. and Ledec, G., 1984. *Environmental Management in Tropical Agriculture*, Westview Press, Inc., Boulder, Colorado, USA.

Jordan, P. (1985). *Schistosomiasis: The Saint Lucia Project*, Cambridge University Press.

Le Bras, M., Guérin, B., Villenave, D. and Dupont, A., 1986. Approche des conséquences sanitaires des aménagements hydro-agricoles en zones tropicales. *Bull.Soc.Path.Ex. 79*: 251-258.

Lee, J.A., 1985. *The Environment, Public Health and Human Ecology*, World Bank, Washington.

Lipton, M. and de Kadt, E., 1988. Agriculture-health Linkages, *WHO Offset Publication no. 104*, Geneva.

Oomen, J.M.V., de Wolf, J. and Jobin, W.R., 1988. *Health and Irrigation, Vol. 2: Case studies.* ILRI Publication no. 45, International Institute for Land Reclamation and Improvement, Wageningen, Netherlands.

Ripert, C.L. and Raccurt, C.P., 1987. The impact of small dams on parasitic diseases in Cameroon, *Parasitology Today 3 (9)*: 287-288.

Schorr, T.S. (ed.) 1984. *Las Represas y sus Efectos sobre la salud*, ECO Guia 1, Pan American Health Organization, Washington, D.C.

Sornmani, S. and Harinasuta, C., 1988. *Water Resources Development and its Impact on Socio-economic and Health with reference to Thailand*, Mahidol University, Bangkok.

World Bank, 1987. *Options and investment priorities in irrigation development.* Unpublished case studies of Mali, Morocco, Peru, Sudan, Thailand, Botswana, Orissa, Kenya and Zambia, presented at the workshop on assessment of human health risks in irrigation and water resource development projects (Paris, 27-29 July 1987).

World Health Organization, 1985, The Control of Schistosomiasis. Report of a WHO Expert Committee, *Technical Report Series no. 728*, Geneva.

World Health Organization, 1986. Resistance of Vectors and Reservoirs of Diseases to Pesticides. Tenth Report of the WHO Expert Committee on Vector Biology and Control, *Technical Report Series No. 737*, Geneva.

World Health Organization, 1987. WHO Expert Committee on Onchocerciasis. Third Report, *Technical Report Series no. 752*, Geneva.

Youdeowei, A., and Service, M. 1983. *Pest and Vector Management in the Tropics*, Longman Group Ltd., London.

WHO FAO UNEP

PEEM 1984

INSTITUTIONAL ARRANGEMENTS TO ENSURE THE INCORPORATION OF HEALTH AND ENVIRONMENTAL SAFEGUARDS IN WATER RESOURCES DEVELOPMENT PROJECTS

Negative effects of water resources development on human health form a classical example of how well-intended sectoral programmes aimed to guarantee or improve people's quality of life in a certain way can have adverse repercussions for the achievement of similar goals set by other sectors. In the growing literature on water resource development associated vector-borne disease problems two recommendations repeatedly turn up: "health considerations should be included in the earliest planning and design stages of a project", and, connected with that, "proper institutional arrangements should be established to ensure the incorporation of health safeguards in water projects". Yet, in very few cases is health an item on the agenda of the first project planning meeting, and even if "proper arrangements" are established, their effective lifespan is usually short.

The institutional structure of the Tennessee Valley Authority is often quoted as a unique example of successful arrangements. TVA was also the starting point for the Panel's fourth technical discussion, which had as an objective to review various models for intersectoral linkages and to recommend a pragmatic approach toward their establishment.

In addition to TVA, case studies from the Philippines and from Sri Lanka were reviewed and are presented in this document. While the arrangements in the Philippines are a successful attempt to set up a functional network between existing entities in the relevant sectors and to further stengthen them, the Mahaweli Authority in Sri Lanka can, on the other hand, be considered to follow the concepts of TVA.

Indeed, the idea of establishing TVA-like organizations to coordinate the development of river basins in less developed countries has been put forward more than once, and the case is also argued in Dr Brook's paper. Whether the TVA concepts will be valid in different political and economic settings remains a question so far unanswered. Certainly the position of the Mahaweli Authority, with its huge external funding, vis-à-vis the sectoral ministries of Sri Lanka is a different one from that of TVA, with its US Senate approved budget, vis-à-vis State bodies.

The Panel's deliberations also covered this issue, and the question was raised whether the creation of large, autonomous bodies such as the Mahaweli Authority should lead to a permanent structure or to a temporary one whose special executive powers would eventually be handed over to sectoral ministries. It was also questioned whether in the latter case the strengthening of sectoral bodies such as the health ministry, would not be hampered at a crucial stage by the creation of an autonomous body.

On the basis of the Panel's recommendations, the preparation was initiated of guidelines for the incorporation of health safeguards in irrigation projects through intersectoral collaboration.

Various authors worked on the guidelines, but their final version is now being written up by Dr M. Tiffen of the Overseas Development Institute. They are scheduled for publication by mid-1989.

Intersectoral action for health in relation to many areas of development, including water resources development, was the subject of the technical discussion during the 39th World Health Assembly (WHO, 1986). Institutional arrangements are a basic requirement to achieve this collaboration. They are, however, ephemeral, as political change and administrative restructuring may lead to shifts of institutions from one sector to the other, and agencies being merged, divided up into two or more entities, or even abolished. In other cases, arrangements have to be not only intersectoral but also international. In this connection, the Agreement on the Action Plan for the Environmentally sound Management of the common Zambesi River System, which was reached under the aegis of UNEP in May 1987 is an important new initiative (UNEP, 1987; David 1988).

The interest in coordination and collaboration between public sectors was also raised, but in a much broader context, by the Report of the World Commission on Environment and Development (1987), which exposed the lack of such an intersectoral approach to be at the root of most environmental problems arising as a result of development.

TENNESSEE VALLEY AUTHORITY: INSTITUTIONAL ARRANGEMENTS FOR HEALTH AND ENVIRONMENTAL PROTECTION IN WATER RESOURCE MANAGEMENT

by

Ralph H. Brooks

HISTORICAL PERSPECTIVE

The Tennessee Valley Authority (TVA) was created as a regional development agency in 1933 by an Act of the United States Congress. It was one element in a broad programme designed to bring the nation out of severe economic troubles. Its structure, however, made it unique among federal agencies. TVA was set up to function as a government-owned corporation with a three-member board of directors. At the same time, it operates with a reasonable degree of autonomy and the flexibility of a private corporation. Each director is appointed by the President of the United States for a term of up to nine years. The terms themselves are fixed and staggered at three-year intervals so that a director might serve all or only part of a term depending on circumstances. Six of the 20 directors who have served on the Board since 1933 have been reappointed.

TVA is an independent agency, and not part of any federal cabinet department. Consequently, interdepartmental conflicts are limited. The TVA Act provided the agency with administrative freedom to meet the special requirements of its programmes and to adopt the methods of administration of successful private as well as public enterprise. It also authorized the board "to provide a system of organization to fix responsibility and promote efficiency." The board decides upon major TVA programmes, organization, and administrative relationships. Responsibility for conducting TVA programmes, applying policies and methods, and performing services is delegated to the major organizational units.

There is a general manager appointed by the board to handle day-to-day operations of the agency. TVA programme activities are handled by three major offices. The office of power and engineering is a self-financing operation deriving funds from the sale of electric power to 160 distribution systems and selected industrial and government customers. On an annual basis the TVA power system is a US$ 4 billion operation.

There are two other programme organizations within TVA: the office of natural resources and economic development and the office of agricultural and chemical development. These offices are primarily funded through congressional appropriations. Planning and budgeting, legal services, personnel, labour relations, health and safety, and other support functions are handled through other organizations reporting to the general manager.

At the time of preparation of this paper Dr Brooks was Assistant-Director, Division of Air and Water Resources, Tennessee Valley Authority, Knoxville, Tennessee. His present position in TVA is Director, Environmental Quality Staff.

TVA serves a region made up of parts of seven states in the Southeast of the United States, including all of Tennessee and portions of Georgia, Alabama, Mississippi, Kentucky, Virginia, and North Carolina (see: figure 1). The heart of this region consists of the rivers and streams that make up the Tennessee River drainage basin. The power service area, however, extends well beyond this area. For this reason TVA activities have, at times, a dual focus. First, there are the 125 counties which make up the Tennessee River watershed. This area covers 40 910 square miles with a population of 4 733 066 people. The power service area, on the other hand, is made up of 170 counties covering 78 000 square miles with a population of 6 847 230 people. This difference in service areas results in extending TVA activities of one kind or another into a region of 201 counties in the seven states, covering 91 000 square miles with a population of 7 842 256.

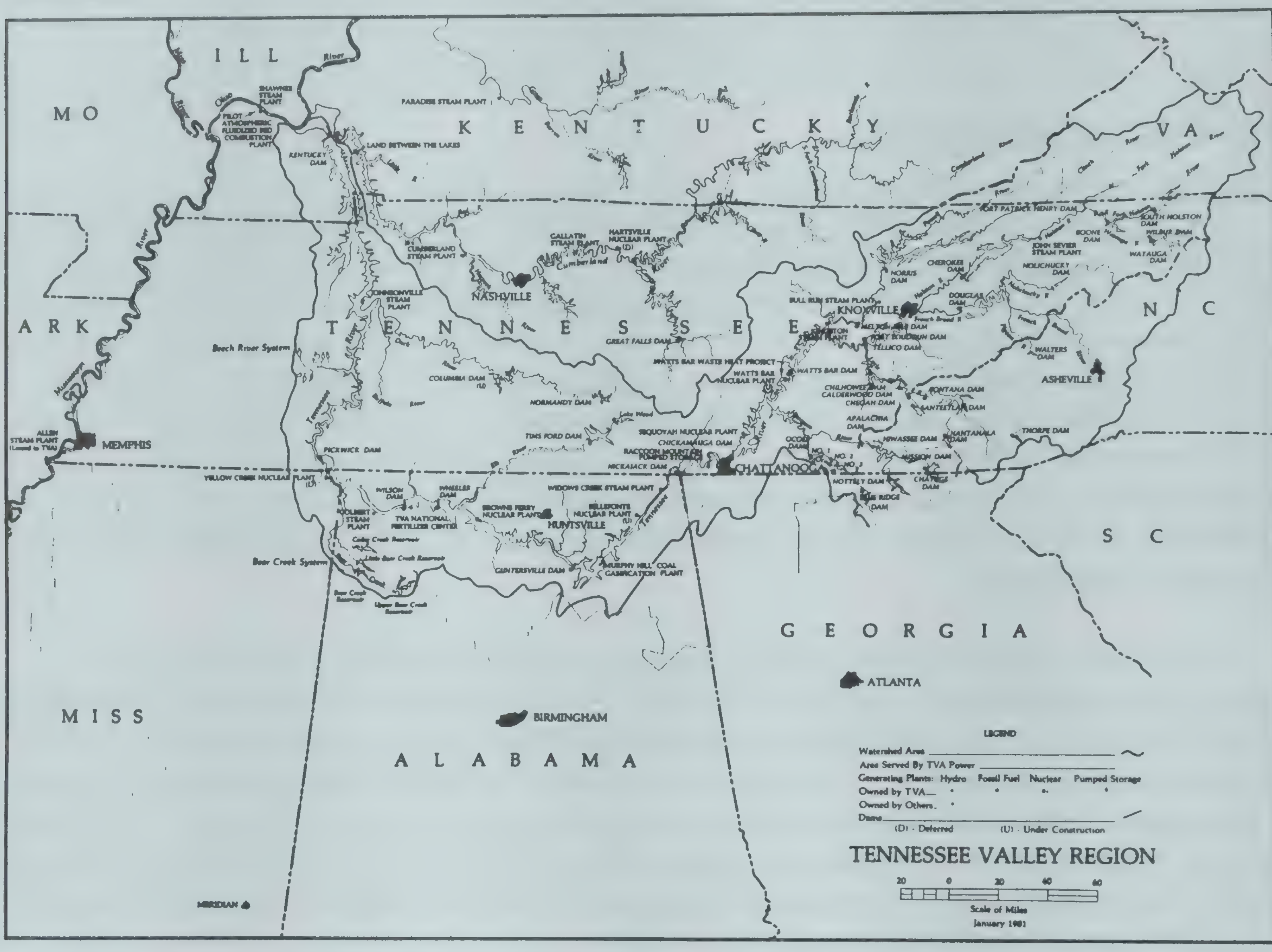


Figure 1. The area covered by the mandate of the Tennessee Valley Authority
Source: TVA, 1984

It should be noted in passing that TVA activities do extend beyond the Tennessee Valley region in some aspects. The agency has a permanent office in Washington, D.C., for instance. Because coal is a major source of fuel for electric power generation, TVA has purchased property in coal-producing areas of the Midwest. Because TVA does business with European equipment manufacturers, the agency has an office on the continent. And because of the TVA nuclear power development, the agency has uranium properties in the western United States and a small office in Casper, Wyoming. In addition, TVA personnel travel across the entire nation and around the world to provide technical assistance or to take part in activities where TVA expertise can be helpful or where TVA interests can be furthered.

As already noted, TVA began its life during what is called the great depression of the 1930s. Various ideas for developing the Tennessee River had been proposed for many years. This river system, fifth largest in the United States, had tantalized regional and national leaders with its undeveloped potential for a hundred years or more. Indian civilizations had developed their towns and villages along the banks of the river and its tributaries. And the settlers of European origin had done the same when they moved into the region, pushing westward from Virginia, North Carolina and South Carolina. They used the river as a transport artery and as a source for water supply.

But it was an unreliable stream with shoals and sinks, with raging waters part of the year and hardly enough to float a boat at other times. Development of a reliable, navigable waterway from Knoxville, Tennessee, to the Ohio River 650 miles downstream became, therefore, one of the primary purposes in establishing the TVA. The other major purpose of developing the river system, and the highest priority in the operation of TVA reservoirs, was flood control. Electric power generation was authorized insofar as it was compatible with the other two priorities of flood control and navigation.

These priorities, coupled with reforestation of the Tennessee Valley and development of the agricultural potential of the region, are what set TVA apart from other depression era institutions established during the mid-1930s. The agency was hardly six years old at the start of World War II in Europe, an upheaval that so radically altered the political, economic, and social structures of the entire world that the agency's roots in times of economic hardship became largely irrelevant. What kept TVA relevant through most of the past half century was the breadth of its mission. This and the unique organizational structure of the agency allowed the statutory flexibility to adjust to rapidly changing conditions created by World War II and the economic and social revolutions that followed.

It must be understood, of course, that the depression was a burden to the Tennessee Valley just as it was to the rest of the nation. But it was not necessarily the shock to the economic nervous system of the region that it was elsewhere. The region had always lagged behind the rest of the country in its development. For many people of the Valley, things were not a lot different in 1933 from what they had been in 1928, or for their parents and grandparents before them. It was a region that had been exploited throughout its history for its timber, its minerals, and its agricultural products. In many places highways were narrow torturous trails through difficult terrain. The river was no help at all. There were rail lines, but they benefited outside interests as much or more than those who lived in the region. Economic deprivation was not simply imposed on the Valley by the circumstances that led to the depression of the 1930s. It was a condition deeply rooted in the region itself. This fact, probably more than any other, makes the TVA experience relevant even today to the conditions that exist in many parts of the world where economic underdevelopment is a heritage of the land. In such areas, change is slow and often painful. But it can occur if there is a determined effort to create conditions which make change possible. That is what TVA set about doing 50 years ago and what the agency has continued to do ever since.

MALARIA IN THE TENNESSEE VALLEY

One of the conditions TVA found in the region at the time of its establishment was the prevalence of malaria which posed a serious threat to the health of the Valley's people. Even

before impoundment of reservoirs began in the area, there were conditions favourable to the major malaria carrier in the South-East, *Anopheles quadrimaculatus* . Depressions in the floodplain along the major streams of the region, such as limestone sinks and potholes, held water for sufficiently long time following floods or heavy rains to provide breeding areas for mosquitoes. Malaria was, therefore, indigenous to the region.

When TVA began its work, three impoundments already existed on the Tennessee River. Surveys in the vicinity of one of these lakes showed malaria prevalence rates between 35% and 65%. It was clear, therefore, that TVA must establish a programme at the very beginning to control this severe health problem with its broad implications for the economic and social well-being of the people of the region.

Based on studies and recommendations by the United States Public Health Service in the early 1900s, regulations had been adopted by various southern states governing the conditions under which water might be impounded. The purpose was to minimize the potential hazard to public health. These regulations generally specified that any person, corporation, or agency desiring to impound water or change the levels of existing impoundments must first obtain a permit from the respective State Board of Health. The regulations further specified certain vector control actions that were to be taken to ensure that disease-transmitting mosquitoes were controlled (United States Public Health Service and TVA, 1947).

Foremost among these specifications were guidelines for reservoir basin preparation, water level regulation, shoreline drainage, and floatage and vegetation control. With these regulations already in place in the Valley States, TVA was legally obligated from the very beginning to include mosquito control in its regional development plans. In support of these regulations and to ensure compliance, TVA prepared a series of vector control specifications for each of its planned reservoirs. These were equal to or surpassed State requirements. In this way, legislative requirements were important in ensuring that mosquito control would be incorporated into impoundment plans for all water resource projects. Legislation of this type may be the best way to ensure that priority is given to vector control in planning and developing water projects. It also helps eliminate conflicts among competing interests.

Community public health ordinances also may be effective, if properly enforced, as a complement to regional control programmes. Local mosquito problems often are related to poor environmental sanitation, such as inadequate solid waste disposal and improper discharge of industrial and domestic wastes. These conditions favour development of mosquito breeding habitats. TVA regional programmes in solid waste and water management provide technical assistance to communities and help eliminate insect vector breeding areas.

There are safeguards against pollutant discharges into the Tennessee River system provided under Section 26a of the TVA Act. Permits for discharge can only be obtained after favourable review. This provides TVA with another opportunity to reduce the potential for mosquito breeding in the reservoir system.

In addition to legislative requirements for vector control based on the impounded waters acts of the seven Valley States, TVA developed its own requirements for vector control. Administrative codes were developed stating agency policy and delegating responsibility to the appropriate programme organization within TVA.

These statements specifically stipulate that vector control will be an integral part of the planning and operation of all water resource development projects. In this way vector control has the clear support of TVA at its highest management level.

Further evidence of TVA support for vector control is contained in environmental impact statements published in 1972 for the agency's vector control programme. This documents TVA's commitment to conduct vector control operations and to do so in accordance with environmentally acceptable practices. This commitment was subject to review by other Federal and State agencies and by the general public before it was accepted for publication as part of the environmental impact statements.

The TVA plan for the economic development of the Tennessee Valley called for a series of nine reservoirs on the Tennessee River itself, and a number of other reservoirs on tributary streams. The first line of defense against mosquitoes was habitat control. The entire area to be impounded was cleared of trees and other vegetation. In some places, shoreline filling was used to eliminate potential shallows where still waters might provide favourable spots for mosquito breeding.

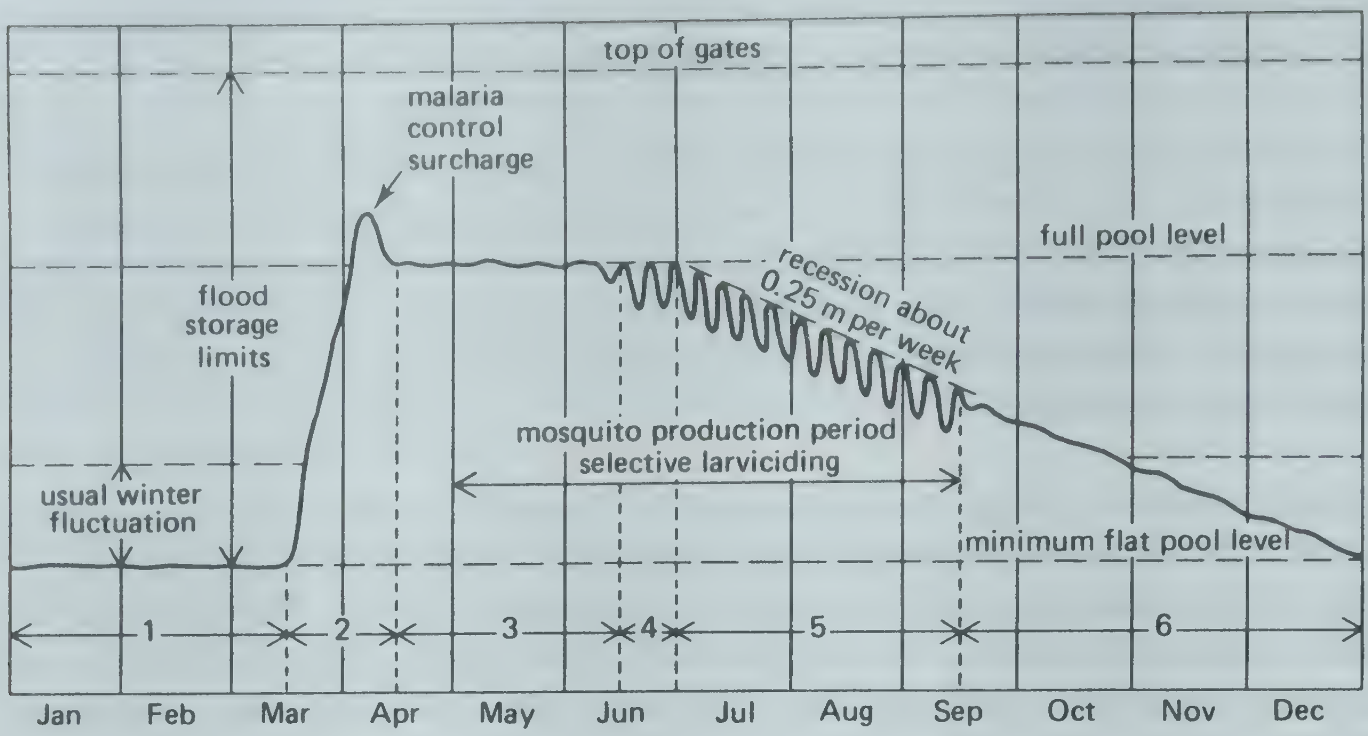
On all reservoirs, a programme of shoreline maintenance was developed and put into effect as the lakes filled. This included mowing and brush cutting to eliminate vegetation favourable for mosquito breeding and maintenance of drainage ditches to eliminate ponded water in the reservoir fluctuation yone.

After impoundment, a programme of water level manipulation on the mainstream of the Tennessee River was initiated (see: figure 2). This programme has two main features. First, there is a weekly fluctuation of reservoir levels of around one foot on a regular cycle, except when heavy rains affect lake levels and streamflow. This fluctuation cycle is part of the normal operation of eight of the mainstream reservoirs. The largest reservoir in the Tennessee Valley system, Kentucky, is more than 100 miles long and does not lend itself to a regular cycle of lake level manipulation.

In the tributary reservoirs, the gradual summer and fall drawdown which begins in late June or early July, combined with fluctuations because of weather or power demands or both has the same effect. Late in the season, on the mainstream reservoirs, there is a gradual drawdown to winter levels which controls mosquitoes directly by drawing water from the vegetated shorelines, as well as by drying out shorelines to permit the performance of cyclical maintenance.

Annual operating schedules for the TVA reservoir system are established each year. A committee representing all reservoir-related programme interests holds an annual meeting to consider reservoir uses and potential problems associated with projected schedules. Planned activities are reviewed and conflicting interests are discussed at length. Water level management for vector control has always received priority consideration by the committee and is incorporated routinely in annual plans. Whenever unusual or non-routine management schemes are considered, public hearings are held to allow concerned citizens to express their views. In this way the public has a voice in the planning for such issues as vector control or other public health concerns.

One other major component of the mosquito control programme which provides control through habitat modification is the management of aquatic plants. There are a number of native



1 LOW WINTER FLOOD CONTROL LEVELS
Control growth of submerged aquatics. Permits marginal drainage and herbicidal operations.

2 EARLY SPRING FILLING
Retards plant growth.
Surcharge – strands drift above full pool level.

3 CONSTANT LEVEL POOL
Provides long–range plant growth.

4 CYCLIDAL FLUCTUATION
Destroys mosquito eggs and larvae.

5 FLUCTUATION AND RECESSION
Destroys eggs and larvae.
Reduces breeding areas.
Provides clean shoreline.

6 RECESSION TO WINTER LEVELS
Permits full shoreline maintenance and improvement operations.

Figure 2. Master plan for water level management for mosquito control of TVA reservoirs
Source: TVA, 1984

species which can provide favourable mosquito breeding habitats, but the major pest in the Tennessee Valley reservoirs is Eurasian watermilfoil. This exotic weed infests significant areas in shallow portions of several TVA lakes. Herbicides such as 2,4-D are used to supplement the control effect of strategic drawdowns which expose these plants to the killing effect of sun or freezing temperatures.

When all of these environmental management measures combined do not produce the desired level of control, insecticides are used to attack mosquitoes at various stages of development in selected areas. Only compounds approved by the Environmental Protection Agency (EPA) are used. Applications are made under regulations developed as part of the Federal Environmental Pesticide Control Act of 1972 (FEPCA). This legislation ensures that applications of pesticides do not create adverse environmental effects. The TVA environmental compliance staff monitors all uses of pesticides to ensure compliance with applicable laws and regulations.

Other mosquito control measures such as habitat manipulation through tree planting and tillage of floodwater mosquito egg beds in marginal zones of reservoirs have been used successfully in limited areas. Selective use and development of reservoir margins can also be effective in limiting man/vector contact.

CURRENT ARRANGEMENTS

In recent years, land use plans have been developed for several reservoirs; ultimately all major reservoirs which have significant amounts of undeveloped marginal lands will be included. These plans will ultimately govern development of lake shorelines and include input from the vector control programme as an integral component.

Other land use requests associated with the reservoir system are reviewed under the TVA Section 26a process. Section 26a of the TVA Act provides for review of applications by individuals, industries, and municipalities for permits allowing use and development of TVA lands or discharges into the reservoir system. Organizationally and administratively TVA provides for review of Section 26a applications by all concerned programme interests. Consequently, the vector control programme has the opportunity to review any actions that might detrimentally affect vector control and either recommend that the permit be denied or indicate ways to mitigate the effect.

The TVA mosquito control programme was so effective against *Anopheles quadrimaculatus* that since 1948 malaria has been virtually unknown in the Tennessee Valley. But, as with all disease, continued vigilance is essential to assure that this scourge does not return to the region.

It also should be understood that the fight against the mosquito vector of malaria has had its effects on other mosquitoes in the Tennessee Valley. There are around 45 mosquito species native to the region, some carriers of other ailments such as dog heartworm and encephalitis. These species fall into three general categories:those which breed in permanent pools (TVA reservoirs are examples), those that breed in temporary pools and floodplains, and those associated with containers of various kinds such as discarded automobile tires, cans, and drums of one kind or another.

The TVA vector control programme is concerned with all three types of mosquitoes. On TVA lands and waters and at agency facilities, steps are taken to combat each variety, as well as to provide technical assistance to communities interested in developing their own abatement programmes. This technical assistance is provided by either contract arrangements or letters of agreement detailing the work to be performed and any reimbursement of incurred costs. TVA also enters into agreements with State and Federal wildlife management agencies which specify operating arrangements for various management units (e.g., waterfowl management, dewatering projects), thereby ensuring compatibility with vector control objectives.

It is clear from the above that successful vector control is not achieved easily. It requires a complex interaction of many elements. Local populations must be involved. State, regional, and national commitment is essential. And this commitment must be continuously renewed from year to year, from generation to generation. In the Tennessee Valley, the inherent flexibility of TVA administrative policies and the organizational autonomy under the TVA Act were major assets in vector control efforts. TVA was able to execute cooperative agreements with other agencies, it had the flexibility for independent action, and it was able to develop the institutional capabilities to carry out an effective programme. The agency'scommitment to adhere to applicable regulations gave vector control a strong legislative foundation. It is likely that only such a far-ranging approach to this threat to public health will succeed.

HEALTH AND ENVIRONMENTAL PROGRAMMES: INSTITUTIONAL ARRANGEMENTS FOR THEIR IMPLEMENTATION IN WATER RESOURCE DEVELOPMENT PROJECTS IN THE PHILIPPINES

by

Cesar L. Tech

THE WATER RESOURCE DEVELOPMENT SECTOR

Current development plan

In the Philippines, water resource development continues to be a major part of the overall national effort in addressing the needs of the fast-growing population and providing necessary components fundamental to the social and economic growth of the country.

The Five-Year Development Plan of the Philippines for the period 1983-1988 provides for an investment of some US$4 340 million in the implementation of water resource development programmes. This allocation covers the investment requirement of the five major sectoral activities, namely: irrigation, water supply, flood control and drainage, hydro/geothermal power generation, and data systems. Irrigation accounts for 27.92% of the total investment plan, water supply accounts for 27.63%, flood control and drainage for 11.99%, hydro/geothermal power generation for 33.40% and data systems for 0.06%.

Agencies involved in water resources development

❒ National Water Resources Council

Under the present governmental institutional structure, there are at least 20 agencies directly or indirectly involved in the development of water resources in the country. Because of the increasing activities in this sector, the National Water Resources Council (NWRC) was created in 1974 to coordinate and integrate the activities of these agencies in matters related to water resource development. Its principal objective is to achieve a scientific and orderly development and management of all the water resources of the country consistent with the principles of optimum utilization, conservation and protection to meet present and future needs.

To carry out its objectives, the Council has two categories of powers: regulatory/executive and advisory. Under the former, the council is to: coordinate and integrate water resource development activities; determine, adjudicate and grant water rights; review and approve all agencies' water resource development plans; undertake river basin surveys, create hydraulic data bases and prepare comprehensive basin-wide plans; formulate and promulgate (a) criteria, methods and standards for basic data collection and project investigation, planning, design and evaluation, and (b) rules and regulations for development and use of water resources; and, con-

At the time of preparation of this paper Mr Tech was Administrator of the National Irrigation Authority of the Philippines; he retired from that position in 1985.

duct/promote research on matters related to water resource development. All these tasks are to be carried out pursuant to an overall national plan.

The advisory powers include recommendations to the National Economic and Development Authority (NEDA) on matters pertaining to water resource development programmes and general water laws and policies.

The Council is composed of the heads of the ministries and line agencies most concerned with water resource development. At present, it has nine members: the Minister of Public Works and Highways (chairman), the Minister of Human Settlement, the Minister of Agriculture, the Minister for Economic Planning, the Minister of Energy, the Minister of Natural Resources, and the heads of the Metropolitan Waterworks and Sewerage Systems (MWSS), National Power Corporation (NPC) and the National Irrigation Administration (NIA).

❒ National Irrigation Administration

The major agency in the country responsible for the development of water resources for irrigation is the National Irrigation Administration (NIA), a government-owned and -controlled corporation established in 1964 from the defunct Irrigation Division of the Bureau of Public Works. To ensure that irrigation development programmes are consistent with the national infrastructure development plan, NIA is attached to the Ministry of Public Works and Highways (MPWH) with its Minister as chairman of the Board of Directors of the agency. The other members of the board are the Minister of Agriculture and the heads of the National Economic and Development Authority, the National Power Corporation and of the National Irrigation Administration itself.

At present NIA is implementing 31 foreign-assisted irrigation projects with financial support from the International Bank for Reconstruction and Development, the Asian Development Bank, the Overseas Economic Corporation Fund, the United States Agency for International Development, International Development Association, and the Philippine-Australian Development Assistance Program. It is also implementing 17 locally funded national irrigation projects and some 288 locally-funded communal projects. The total service area of the on-going irrigation projects is about 616 000 hectares which includes the rehabilitation of about 166 000 hectares of existing service areas and generation of 450 000 hectares of new areas. Other than the on-going irrigation projects, NIA currently operates and maintains 127 national irrigation systems servicing over 549 000 hectares. To date, the total service area of all types of operating irrigation systems in the Philippines is about 1.4 million hectares representing about 44% of the total potential irrigation area.

❒ Other government agencies and institutions

As mentioned earlier there are at least 20 government agencies and institutions directly or indirectly involved in water resource development in the country. In addition to the two mentioned above, another government agency developing water resources for irrigation is the Farm Systems Development Corporation. Unlike NIA, this corporation develops only communal and other small-scale irrigation projects. There are other government agencies with specific sectoral

functions in water resource development. Some of these include: the National Power Corporation and the National Electrification Administration for hydropower; the Metropolitan Waterworks and Sewerage Systems, the Local Water Utilities Administration, and the Rural Waterworks Development Corporation for water supply; and the Ministry of Public Works and Highways for flood control and drainage, and rural water supply.

To strengthen regional development efforts of the government, several Integrated Area Development institutions were established. Foremost of these is the National Council on Integrated Area Development (NACIAD) with the Prime Minister of the Republic of the Philippines as chairman.

THE HEALTH AND ENVIRONMENT SECTORS

Current health policies and the Ministry of Health

While the public health efforts of the past government were limited to sanitation, disease eradication and control, today the concerns have become broader and include a wide range of environmental aspects, such as adequate drinking water supply, a proper solid waste and sewage disposal system, improved housing facilities, and nutrition and family planning programmes.

The extent of government health improvement efforts can be gauged by the objectives and functions of the Ministry of Health (MOH). These objectives include the prevention and control of communicable diseases, such as eradication of malaria and control of schistosomiasis, and the provision of adequate health services in the rural areas. To attain these objectives, the government has created several offices within the MOH including six bureaus, namely: the Bureau of Health Services, the Bureau of Medical Services, the Bureau of Dental Services, the Bureau of Research and Laboratories, the Bureau of Quarantine, and the Bureau of Food and Drugs. Two other offices were also created within the MOH especially to carry out programmes for the control of vector-borne diseases. These are the Malaria Eradication Services (MES) for the control and eradication of malaria and the Schistosomiasis Control and Research Services (SCRS) for the control of schistosomiasis. Through these central offices and its various regional, provincial and rural health units all over the country the MOH is permanently providing services aimed to promote human health and a good environment.

Vector-borne disease control

The most important vector-borne diseases in rural areas of many parts of the Philippines are schistosomiasis and malaria. Their distribution often coincides with irrigated agriculture. Schistosomiasis is a debilitating disease caused by a blood fluke of the genus *Schistosoma* . In the Philippines and other parts of East and South East Asia, the species *S. japonicum* is specifically responsible for the disease, and *Oncomelania quadrasi* is its snail intermediate host species. It affects not only man but several other species of vertebrates. In 1982, more than a million individuals in the Philippines, mostly farmers and their families in 158 towns and 22 provinces in Southern Luzon, Visayas and Mindanao, were immediately exposed to the disease with an estimated 199 000 people infected. The known area of snail infestation is about 22 780 hectares.

Malaria, like schistosomiasis, is a major public health problem in the Philippines, more especially in the Cagayan Valley and the islands of Palawan and Sulu. It is caused by parasites belonging to the genus *Plasmodium* . The principal vector in the Philippines is *Anopheles flavirostris* , a small mosquito measuring only about 3 to 4 mm from the head to the tip of the abdomen and standing at a 60° angle to the surface. It breeds only in fresh, slow-flowing water such as in creeks and springs, never in stagnant muddy water. The adult mosquitoes bite at night when the temperatures drop. In 1982, there were 97 531 confirmed cases of malaria distributed over the twelve regions of the country.

Development of the schistosomiasis control programme and the Schistosomiasis Control and Research Services of the Ministry of Health

The recorded history of *Schistosoma japonicum* in the Philippines dates back to the year 1906 when its occurence was first described. The discovery of the snail intermediate host in 1932 in a pond and small brook in the town of Palo in the province of Leyte marked the beginning of the campaign against schistosomiasis in the Philippines. In 1940, the then Bureau of Health conducted comprehensive field surveys to gather information on the distribution of the disease in the islands of Mindanao, Leyte and Mindoro. Research on the parasite and treatment were interrupted during the Second World War. From immediately after the war up to the present, activities related to the control of the disease have progressed significantly.

In 1949-1950, under the auspices of the Department of Health (now Ministry of Health), six field units were created to undertake mass stool examinations, snail surveys, and control, treatment and educational propaganda. This campaign covered 35 towns in 10 provinces in Mindanao, Leyte, Mindoro and Samar. The surveys elucidated some features of the disease, such as prevalence rates ranging from 12.1% to as high as 50.7%. These surveys also revealed the important fact that the prevalence of other species of intestinal parasites could reach as high as 99% in some groups of the population.

In 1951 the Division of Schistosomiasis was created within the Department of Health in recognition of the importance of schistosomiasis as a public health problem. In the following year, at the request of the Philippine Government, the World Health Organization (WHO) sent a team of consultants. The team concluded that the disease problem was being approached almost entirely from a medical viewpoint, and that the measures thus applied did not seem to be very effective, and it recommended the gathering of more information on other aspects including biology of the snail intermediate host, and control strategies using engineering, agriculture and health education activities. This led to the establishment of the schistosomiasis control programme in Palo, Leyte in 1952. Aside from WHO assistance, other support came from the Foreign Operation Administration of the United States and the Philippine Council for United States Aid.

Various studies were carried out on epidemiology, control, and other related aspects of the disease. Their results eventually led to the adoption of a classical four-pronged approach to the control of the disease, namely: case detection and treatment; health education; environmental sanitation; and snail control through agro-engineering methods and the use of chemicals.

To be able to cope with the growing activities for the control of schistosomiasis in the country, the then Department of Health strengthened the Division of Schistosomiasis to become

Schistosomiasis Control and Research Services (SCRS). Some of the functions of the SRCS are: to gather information on the prevalence and intensity of schistosomiasis in the whole country; to conduct research on the immunology of schistosomiasis and other host-parasite relationships; to carry out drug and molluscide screening; to conduct studies on the ecology of the snail vector and other aspects which could lead to more effective and economical methods of controlling the disease; and to implement control programmes in all endemic areas. In carrying out its functions, the SCRS organized several schistosomiasis control teams in all endemic areas. SRCS was directly responsible for the planning and implementation of all schistosomiasis control programmes in the whole country. A reorganization within the MOH early this year, however, limited therole of the SRCS to a staff function with the Provincial Health Offices (PHOs) now directly implementing the programme. All schistosomiasis control teams were therefore placed under the supervision of PHOs.

Schistosomiasis control programme coordination and the Schistosomiasis Control Council

The need for multi-agency coordinated and concerted efforts in the control of schistosomiasis in the Philippines prompted the Government to create, in 1965, the National Schistosomiasis Control Commission which was in 1976 restructured into Schistosomiasis Control Council by Presidential Decree No. 893. The Council is primarily responsible for the coordination and integration of all schistosomiasis control programmes, projects and activities of government agencies and bodies concerned. The governing body of the Council is a Board of Directors with the Minister of Health as Chairman, and the Minister of Public Works and Highways, the Minister of Local Government and Community Development, the Minister of Agriculture, the Minister of Education and Culture, the President of the Philippines Medical Association and the Administrator of the National Irrigation Administration as members. An Executive Committee headed by the Council's Executive Director is organized to review and recommend to the Board of Directors national programmes on the control of schistosomiasis in the country. Aside from the Executive Director, the Committee is composed of one representative each from the agencies represented in the Board of Directors and three others, one each from the National Economic and Development Authority, the Ministry of Social Services and Development, and the Ministry of Budget. The execution of all activities necessary to achieve the objectives of the council is entrusted to technical staff under the Executive Director.

Development of the malaria eradication programme and the Malaria Eradication Service of the Ministry of Health

The establishment, in 1926, of a Malaria Control Section in the then Bureau of Health marked the beginning of organized efforts in the Philippines for studying the epidemiology of malaria and for controlling the disease. In the Philippines, as in most tropical countries, the scope of malaria control in rural areas was limited by the impracticability of methods then available, and the great expenditures involved in their implementation. The advent of Dichloro-Diphenyl-Trichloroethane (DDT) in the post-World War II period changed the picture and the country lost no time in taking advantage of this change.

Several small-scale trials to test the effectiveness of DDT under Philippine conditions were carried out in the country. These were followed by a large-scale pilot project in Mindoro Island in 1952-1954 with technical and financial assistance from WHO and the United States Government.

Based on the finding of the pilot projects, a six-year Philippine-United States plan of malaria control was launched in 1954 for the protection of an estimated 7.5 million population at risk. In 1956, the term control was substituted by eradication in the title of the project, with the consequent implication that spraying was extended from three to four years. The results of the project were spectacular and a parasite survey conducted in 1958 showed a marked reduction in malaria cases in most parts of the country.

Before 1960, when the Government gave the responsibility for implementing the malaria eradication programme to the Regional Health Offices, the Division of Malaria Eradication of the Ministry of Health had direct administrative and technical responsibility over the field units, with the malaria eradication staff providing the necessary technical advisory services without any direct line of authority over field personnel. In 1966, the direct responsibility for the programme was given back to the Division of Malaria Eradication, but as part of a new structure. Republic Act No. 4832 reconstructed the Division into the Malaria Eradication Service (MES). The law provided the MES with legal authority and financial backing and it was made a separate major office of the Department of Health (now Ministry of Health). The provisions of the Act included central direction and control, and adequate staff for field supervision and implementation of operations. The functions of MES, as provided by the Republic Act No. 4832, are: to formulate schemes and adopt unified and coordinated measures for the eradication of malaria; to assign or re-assign malaria personnel and resources whenever exigencies so demand; to adopt measures which may relate to the spraying of buildings and other premises with insecticide, to malaria surveys, to medical examination of the people and treatment of persons suffering from malaria, and to delimitation of malarious and non-malarious areas; and, to adopt any other measures considered necessary to achieve malaria eradication in the country.

Early this year, another reorganization was made within the MOH which limited the MES to a staff role with the Provincial Health Offices (POHs) now having the direct line responsibility in the eradication of malaria. In this connection the 33 malaria units in the country were placed under the direct supervision of the different Provincial Health Offices.

IRRIGATION DEVELOPMENT AND THE CONTROL OF VECTOR-BORNE DISEASES

The schistosomiasis control programme in irrigation projects

❒ The control programme

The experience of water resource development for irrigation in the Philippines shows that it often, but not always, contributes to the spread of the disease, as the snail intermediate hosts expand their distribution to formerly unaffected areas. Also, in irrigation projects where there is no provision for adequate drainage, previously small waterlogged areas serving as habitats for the snail intermediate hosts expand, thus increasing the potential for disease transmission. It is mainly for these reasons that schistosomiasis control programmes are incorporated in irrigation development projects which service areas endemic for or with the potential to become endemic for the disease.

At present, NIA has ten on-going projects and one completed project with health and environmental components. These projects receive financial assistance either from ADB or IBRD.

Eight of the projects, including the completed one, have schistosomiasis programmes; two have pure health services and environmental components; and one has a malaria control component (see: table 1).

In irrigation projects with a schistosomiasis control component this is usually divided into two categories, engineering and health services. The engineering aspect is composed of improvement of existing drainage channels and construction of new ones; implementation of improved water management schemes; construction of footbridges; construction of Barangay Health Centres; and development of rural water supply. The health services aspect is composed of health education; diagnosis and treatment; environmental sanitation; and snail control through the use of molluscicides.

TABLE 1. On-going and completed irrigation projects with a health and environmental component.

NAME OF PROJECT AND LOCATION	AREA COVERED HAS.	IMPLEMENTATION PERIOD	ESTIMATED TOTAL COST $'000	FUND SUPPORT	PRINCIPAL EXECUTING AGENCY	HEALTH AND ENVIRONMENTAL COMPONENT			
						COST $'000	% OVER TOTAL	NATURE	EXECUTING AGENCY
ON-GOING PROJECTS									
1. Allah River Irrigation Project, South Cotabato and Sultan Kudarat	18,812	June/78 to Dec./78	37,828	ADB	NIA	1,809	4.78	Rural health services and rural water supply	MOH and MPWH
2. Bukidnon Irrigation Project, Bukidnon	12,000	Oct./79 to Dec./87	17,743	ADB	NIA	2,626	14.80	Schistosomiasis control and rural health services	MOH
3. National Irrig. Systems Improvement Project, Package I, Regions 1,2, & 8	49,250	Dec./78 to Dec./84	80,642	IBRD	NIA	15,650	19.50	Schistosomiasis control, rural health services and rural water supply	MOH and MPWH
4. National Irrig. Systems Improvement Project, Package II, Regions 4,5,6,9, 10,11 and 12	80,900	Jan./79 to Dec./85	97,500	IBRD	NIA	5,700	5.84	Schistosomiasis control and rural health services	MOH
5. Philippine Medium Scale Irrigation Project, Mindoro and Palawan	41,480	Jan./79 to Dec./89	83,214	ADB	NIA	400	0.48	Malaria control and rural health services	MOH
6. Samar Integrated Rural Development Project,* Samar	2,000	Feb./80 to Dec./84	43,000	IBRD	NACIAD	1,400	3.26	Schistosomiasis control, rural health services and water supply	all member agencies of SCC
7. Second Agusan Irrigation Project, Agusan	6,200	Jan./79 to Dec./86	15,928	ADB	NIA	2,213	13.89	Schistosomiasis control, rural health services and water supply	MOH and MPWH
8. Second Davao Irrig. Project Davao del Norte	15,737	Apr./77 to Dec./84	25,674	ADB	NIA	1,300	5.14	Schistosomiasis control, rural health services and water supply	MOH and MPWH
9. Third Davao Irrig. Project Davao del Norte	9,000	Apr./83 to Dec./88	33,765	ADB	NIA	4,664	13.81	Schistosomiasis control, rural health services and water supply	MOH and MPWH
10. Tago River Irrig. Project Surigao del Sur	14,500	Jul./77 to Dec./87	30,325	ADB	NIA	452	1.49	Rural health services and rural water supply	MOH and MPWH
COMPLETED PROJECT									
1. Philippine Rural Development Project*, Mindoro	15,540	Jul/75 to Dec./83	12,106	IBRD	NACIAD	2,700	22.30	Schistosomiasis rural health services and water supply	all member agencies of SCC

* This is an integrated area development project wherein health and environmental component is on the same level as the irrigation component.

Source: National Irrigation Administration, Philippines (1984)

❐ Programme implementation and institutional arrangements

The implementation of a schistosomiasis control programme in irrigation project areas depends on whether the programme is just one of several components of an integrated area development project or a component of an irrigation development project. In an integrated area development project, for example the Philippine Rural Development Project (PRDP), on the island of Mindoro, the National Council on Integrated Area Development is the principal executing agency responsible for the implementation of the programme. The National Irrigation Administration and the Ministry of Public Works and Highways are, in this case, only cooperating agencies (see: figure 1). On the other hand, when the programme is only a component of an irrigation project, NIA is the principal executing agency responsible for the implementation of the programme and MOH and MPWH are the cooperating agencies.

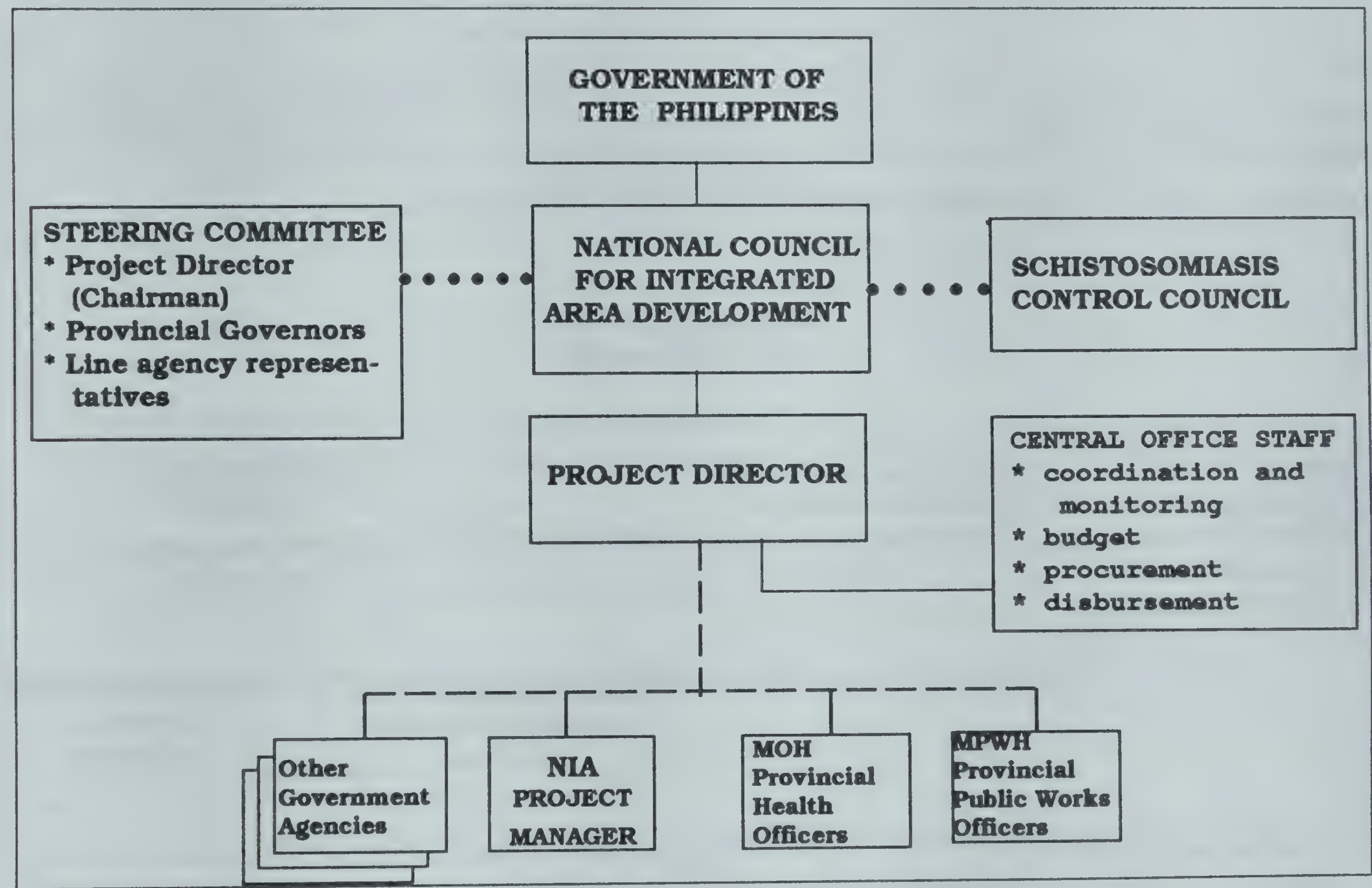


Figure 1. Institutional structure for the implementation of the schistosomiasis control Programme for a Philippines rural development project (an example of an an integrated area development project).

In the latter case, before the start of project implementation, NIA initiates the preparation of a memorandum of agreement with the MOH (Annex 1) to formally set the duties and responsibilities of both agencies relative to the schistosomiasis control programme. As usually contained in the agreement, MOH is responsible for the health services component of the programme and NIA for the engineering component, except where it relates to rural water supply which is the responsibility of the MPWH. A similar memorandum of agreement between NIA and MPWH (Annex 2) is also usually prepared to ensure that the responsibilities of the latter are properly

attended to. In this framework NIA also provides logistical support to both MOH and MPWH such as procurement of supplies and materials and provision of vehicles and field personnel, and some incentives in the form of honoraria to MOH and MPWH employees stipulated to work for the programme.

The NIA carries out its programme duties and responsibilities through its project offices, with the project managers (regional irrigation directors in some projects) as the main responsible persons. The MOH, on the other hand, implements the programme through the Schistosomiasis Control and Research Services and Provincial Health Offices. Before 1984, SRCS directly supervised the implementation of the programme through its various schistosomiasis control teams organized in all endemic and potentially endemic areas in the country and, if this was not adequate, through special teams to specifically implement the programme in a particular irrigation project. SCRS had an overall control of its activities from the head office down to the field. with the PHOs playing only supporting roles. But in the beginning of 1984 the MOH was reorganized and SCRS now plays a staff role. In the new structure the PHOs are directly responsible for the implementation of schistosomiasis control programmes. The different schistosomiasis control teams which previously reported directly to SCRS now report directly to the PHOs. Figure 2 shows the present institutional arrangements in the implementation of schistosomiasis control programmes in irrigation projects in the Philippines.

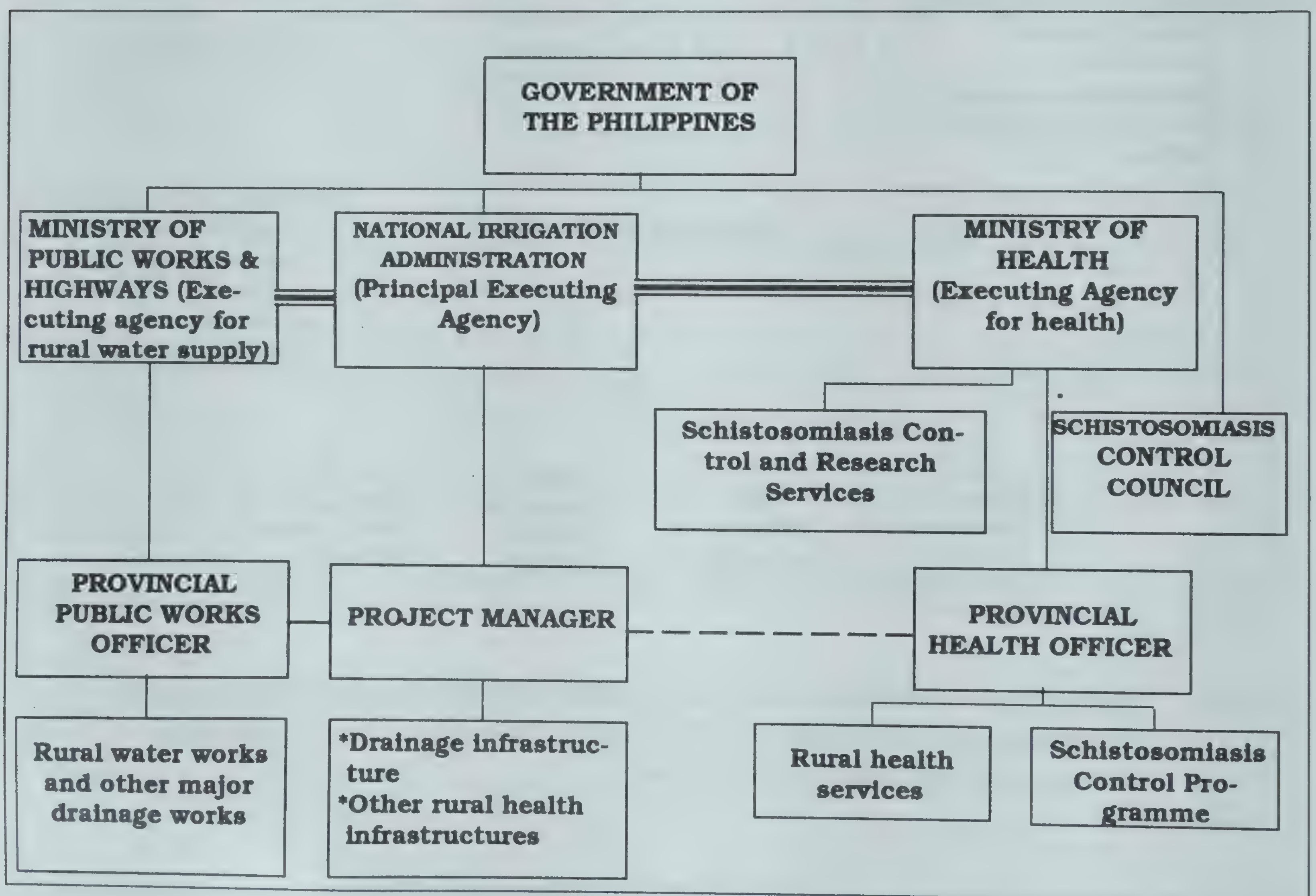


Figure 2. Existing institutional structure for the implementation of schistosomiasis control in irrigation projects (═══ indicates a linkages under an official memorandum of understanding).

The MPWH implements its programme roles and responsibilities through its district offices with the district engineers as the directly responsible persons.

The disbursement and management of the foreign component of health programme funds in irrigation projects is administered by NIA. The MOH, on the other hand, controls the national counterpart funds in the case of health services and the MPWH in the case of rural water supply and large drainage works. (see: Figure 3)

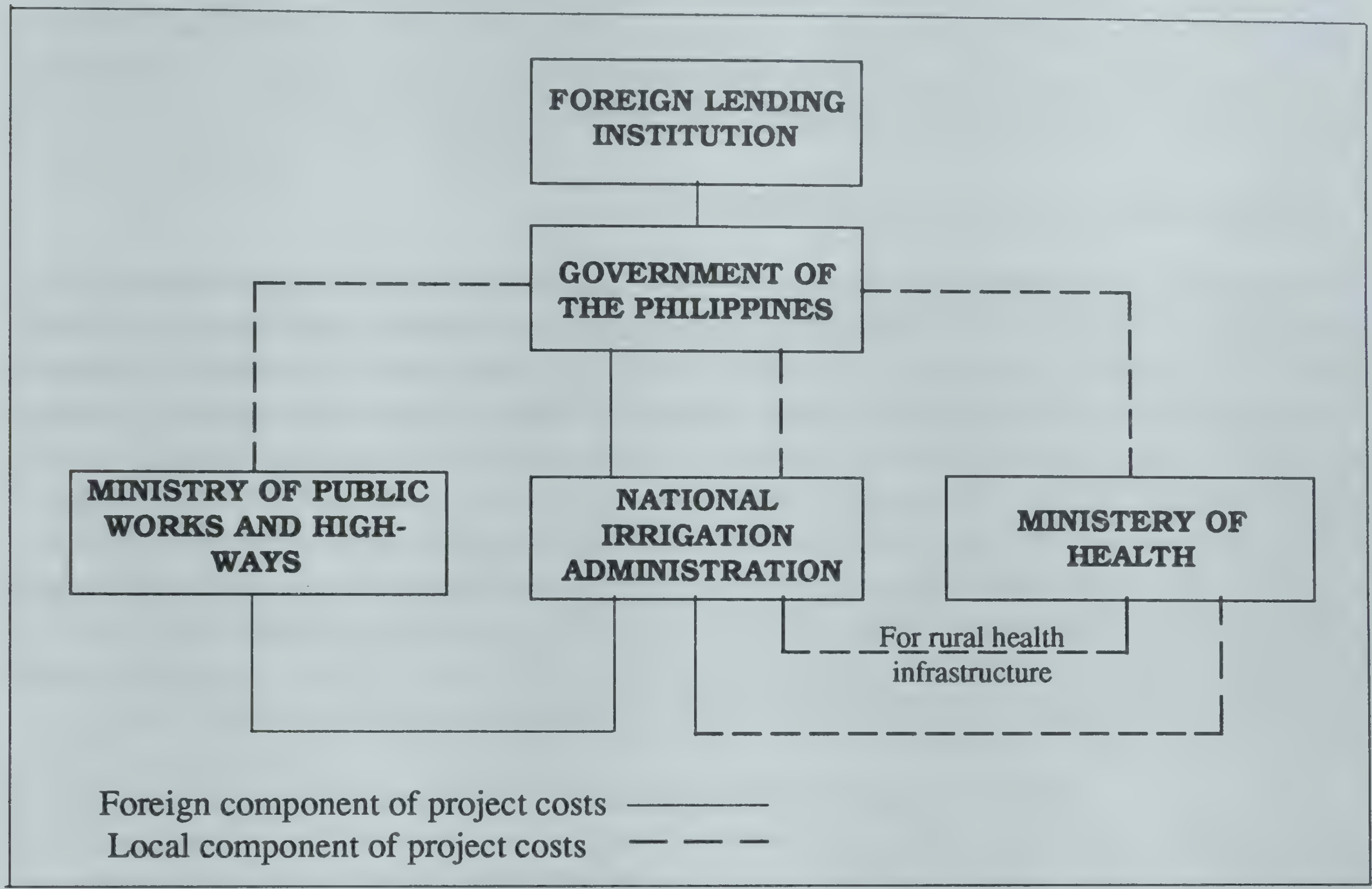


Figure 3. Present flow of financial support for the implementation of irrigation projects with health and environmental components.

The malaria control programme in the Philippines Medium Scale Irrigation Project

❒ The control programme

Experience in the Philippines and abroad shows that the construction of irrigation works may positively or negatively affect the transmission of malaria. In the process of construction some breeding sites of the vector mosquitoes may be destroyed; new sites may, however, also be created. The movement of workers and their families from malarious to non-malarious areas or *vice-versa* may further disturb the eco-epidemiological balance of the factors contributing to malaria transmission.

The inclusion of the malaria control programme as an integral component of the on-going Philippines Medium Scale Irrigation Project (PMSIP) is in recognition of the possible adverse impact of the project on the spread of malaria. In principle, the Ministry of Health already implements malaria control programmes in practically all irrigation project areas endemic or potentially endemic for malaria, such as in the project areas of PMSIP located in the islands of Mindoro and Palawan. This is, however, not so effective because of limited financial support from the government. The control currently implemented in the PMSIP context generally attempts to strengthen the on-going programme of the Malaria Eradication Service of the MOH.

Specifically, it aims to interrupt malaria transmission, reduce morbidity and prevent mortality through intensified application of attack and surveillance measures; health education and information drive; community and intersectoral participation; and, programme monitoring and evaluation. Some of the specific activities are the following: training of personnel; residual DDT spraying of houses; Ultra Low Volume spraying of selected areas; weekly larviciding of selected breeding places; introduction of biological measures (larvivorous fish); passive and active case detection and treatment; epidemiological investigation; parasitological examination; health education and information campaign; and clearing of rivers and creeks.

❐ Implementation and institutional arrangements

The NIA is directly responsible for the implementation of all components of irrigation projects such as the malaria control and eradication programme. Considering that the agency does not have the technical capacity for implementing the programme, the NIA coordinates the implementation of the programme with the MOH through the Malaria Eradication Service. To ensure an effective implementation of the programme, a memorandum of agreement (Annex 3) was prepared between the two agencies before the start of project implementation. The agreement provides that the MES is directly responsible for the actual implementation of the malaria control programme, with the NIA through its project office providing logistical support, particularly in the recruitment of personnel, procurement of equipment, supplies and material and in disbursement of programme funds. A reorganization in the MOH early this year, however, limited the MES to a staff role with the Provincial Health Offices now playing the executive role.

Since its start in 1980, the programme has been proceeding generally smoothly, except for some problems encountered in the procurement of supplies and materials from abroad and other minor problems encountered due to the reorganization within the MOH. This indicates that the existing institutional arrangements (figure 4) for the implementation of the programme are adequate.

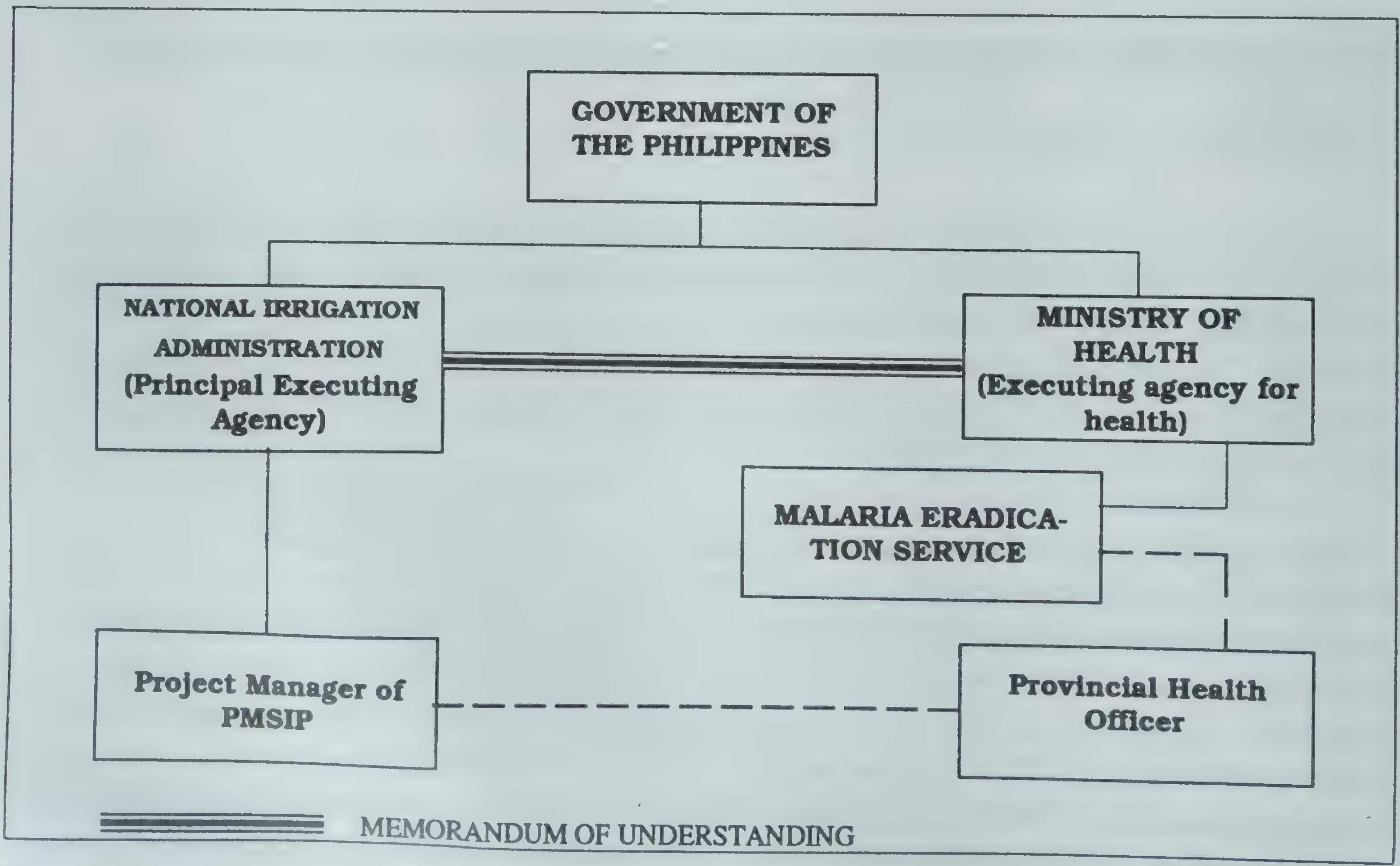


Figure 4. Present institutional structure for the implementation of a malaria control programme as a component of the Philippine Medium Scale Irrigation Project (OMSIP).

OTHER IRRIGATION RELATED ENVIRONMENTAL AND HEALTH CONSIDERATIONS

Environmental Impact Assessment

Irrigation projects, particularly those requiring the construction of dams and reservoirs, are among the most sensitive of all development projects due to the changes they may cause in the environment. While such projects are no doubt of importance to national economic development, all too often in the past their adverse impacts on the environment have not been taken into account at the project planning stage.

The need to assess the potential impacts of projects on the environment arose from the failure of traditional feasibility studies to capture and reflect the necessary resource and environmental factors into project planning. In the Philippines, environmental impact assessment gained impetus after the enactment into law of the Philippine environmental policy decree (Presidential Decree No. 1151). Section 4 of this decree stipulates that project proponents, whether from the public or private sectors, shall prepare, file and include in every action, project or undertaking which significantly affects the quality of the environment a detailed statement on: the environmental impact of the proposed action, project or undertaking; any degree of environmental effect which cannot be avoided should the proposal be implemented; an alternative to the proposed action; a determination that the short-term uses of the resources of the environmental are consistent with maintenance and enhancement of the long term productivity of the same; and whenever a proposal involves the use of depletable or non-renewable resources, a finding must be made that such use and commitment are warranted.

The rules and regulations implementing Presidential Decree No.1151 became effective in June 1978. The all-encompassing coverage of development projects and the dearth of manpower or expertise to make the systems fully operational, however, characterized the requirement as rather ambitious for a developing country like the Philippines. In 1979, Presidential Decree No. 1586 scaled down the scope of coverage of the impact assessment system by specifying that only those projects or areas which are environmentally critical will automatically fall within the provisionof the environmental assessment requirements. Presidential Proclamation No. 2146, which was issued in 1981, identified three types of environmentally critical projects (i.e., infrastructure projects, heavy industries, and resource extractive industries) and twelve kinds of environmentally critical areas (e.g., waterbodies, recharge areas of acquifers, etc.).

Significant steps have already been taken towards establishing the institutional framework required in the implementation of the environmental impact assessment in water resource development projects. Since 1980, the various major agencies with a mandate in the water resource development sector in the Philippines have been meeting and have agreed on coordinating in this connection in their respective projects.

Actually, NIA normally assesses the environmental impacts of proposed foreign-assisted irrigation projects as required by the foreign financing institutions. The assessment procedure is, however, not as comprehensive as in the case of the environmental impact assessment required by the Philippine environmental policy. In compliance with this policy, NIA is strengthening its capability for conducting environmental impact assessment through training of selected agency personnel by an environmental adviser under a grant by the Australian Government.

The task of monitoring the implementation of the environmental impact assessment programmes in all development projects and the consequent review of their results are the responsibilities of the National Environmental Protection Council created by virtue of Presidential Decree No. 1121. The council is composed of the Minister of Human Settlement, as chairman; the Minister of Natural Resources as Executive Officer; and as members, the Presidential Assistant for Economic Development and Affairs, the Minister of Public Works and Highways, the Minister of Local Government and Community Development, the Minister of Trade and Industry, the Minister of Budget, the Minister of Energy, the Minister of National Defense, the Minister of the National Science and Technology Authority, the Deputy Chairman of the Human Settlements Regulatory Commission, the Commissioner of the National Pollution and Control Commission, and the Chairman of the Executive Committee of the Environmental Centre of the Philippines.

Water quality improvement programmes in existing irrigation systems

Concerned with the growing environmental problems associated with the degradation of the quality of irrigation water from rivers and creeks, the NIA has been employing measures to prevent the entry of pollutants to irrigation systems. In1979, NIA coordinated with the National Pollution Control Commission, the Bureau of Mines of the Ministry of Natural Resources, the Ministry of Agriculture and the different mining companies regarding mine tailings problems in some of the agency-operated irrigation systems. The NIA proposed several non-structural and structural control measures which were accepted by the different agencies involved. As regards other pollutants affecting irrigation systems, such as wastes from geothermal plants, food processing plants, etc., NIA coordinates with the National Pollution Control Commission and the concerned public and private entities regarding studies and measures for correcting the problems.

The NIA, in coordination with the Philippine Council for Agriculture and Resources Research and Development, is currently conducting a study on the extent of irrigation water pollution in national irrigation systems throughout the country. The study primarily aims to identify the sources and causes of irrigation water pollution and measures for their abatement as related to: mine tailings, agricultural chemicals, industrial and agricultural effluents, and erosion and sedimentation. With this study, NIA hopes to develop a coordinated programme of preventing the pollution of irrigation water in the country and consequently reducing the health and environmental hazards it poses to the communities in the irrigated areas.

CONCLUSIONS AND RECOMMENDATIONS

In the Philippines, environmental and health considerations are adequately included in the planning and design of irrigation development projects, and are reflected in concrete measures at the construction phase. The present institutional arrangements with NIA, MOH and MPWH as the principal agencies involved seem to be satisfactory, as demonstrated by the on-going foreign-assisted irrigation projects, at least during the planning, design and construction phases. Some problems, however, may arise upon project completion. Experience shows that drainage channels constructed as part of the schistosomiasis control programme in some of the irrigation projects are left unmaintained due to lack of funds. To prevent such a situation and to ensure the continuity of some important activities related to the control of schistosomiasis, particularly the maintenance of health infrastructure in the period beyond project implementation, it is very

The disbursement and management of the foreign component of health programme funds in irrigation projects is administered by NIA. The MOH, on the other hand, controls the national counterpart funds in the case of health services and the MPWH in the case of rural water supply and large drainage works. (see: Figure 3)

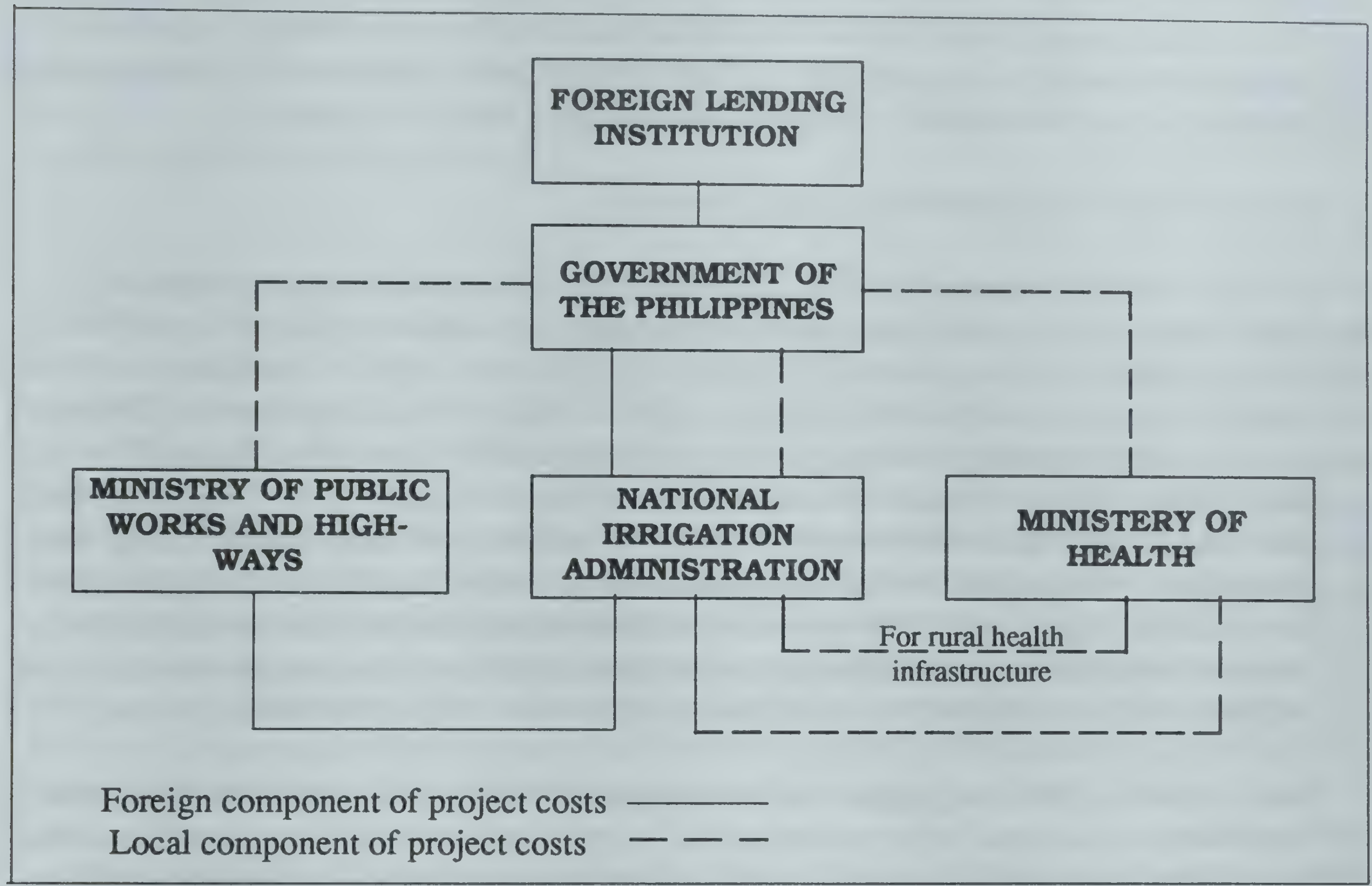


Figure 3. Present flow of financial support for the implementation of irrigation projects with health and environmental components.

The malaria control programme in the Philippines Medium Scale Irrigation Project

❐ The control programme

Experience in the Philippines and abroad shows that the construction of irrigation works may positively or negatively affect the transmission of malaria. In the process of construction some breeding sites of the vector mosquitoes may be destroyed; new sites may, however, also be created. The movement of workers and their families from malarious to non-malarious areas or *vice-versa* may further disturb the eco-epidemiological balance of the factors contributing to malaria transmission.

The inclusion of the malaria control programme as an integral component of the on-going Philippines Medium Scale Irrigation Project (PMSIP) is in recognition of the possible adverse impact of the project on the spread of malaria. In principle, the Ministry of Health already implements malaria control programmes in practically all irrigation project areas endemic or potentially endemic for malaria, such as in the project areas of PMSIP located in the islands of Mindoro and Palawan. This is, however, not so effective because of limited financial support from the government. The control currently implemented in the PMSIP context generally attempts to strengthen the on-going programme of the Malaria Eradication Service of the MOH.

Specifically, it aims to interrupt malaria transmission, reduce morbidity and prevent mortality through intensified application of attack and surveillance measures; health education and information drive; community and intersectoral participation; and, programme monitoring and evaluation. Some of the specific activities are the following: training of personnel; residual DDT spraying of houses; Ultra Low Volume spraying of selected areas; weekly larviciding of selected breeding places; introduction of biological measures (larvivorous fish); passive and active case detection and treatment; epidemiological investigation; parasitological examination; health education and information campaign; and clearing of rivers and creeks.

❐ Implementation and institutional arrangements

The NIA is directly responsible for the implementation of all components of irrigation projects such as the malaria control and eradication programme. Considering that the agency does not have the technical capacity for implementing the programme, the NIA coordinates the implementation of the programme with the MOH through the Malaria Eradication Service. To ensure an effective implementation of the programme, a memorandum of agreement (Annex 3) was prepared between the two agencies before the start of project implementation. The agreement provides that the MES is directly responsible for the actual implementation of the malaria control programme, with the NIA through its project office providing logistical support, particularly in the recruitment of personnel, procurement of equipment, supplies and material and in disbursement of programme funds. A reorganization in the MOH early this year, however, limited the MES to a staff role with the Provincial Health Offices now playing the executive role.

Since its start in 1980, the programme has been proceeding generally smoothly, except for some problems encountered in the procurement of supplies and materials from abroad and other minor problems encountered due to the reorganization within the MOH. This indicates that the existing institutional arrangements (figure 4) for the implementation of the programme are adequate.

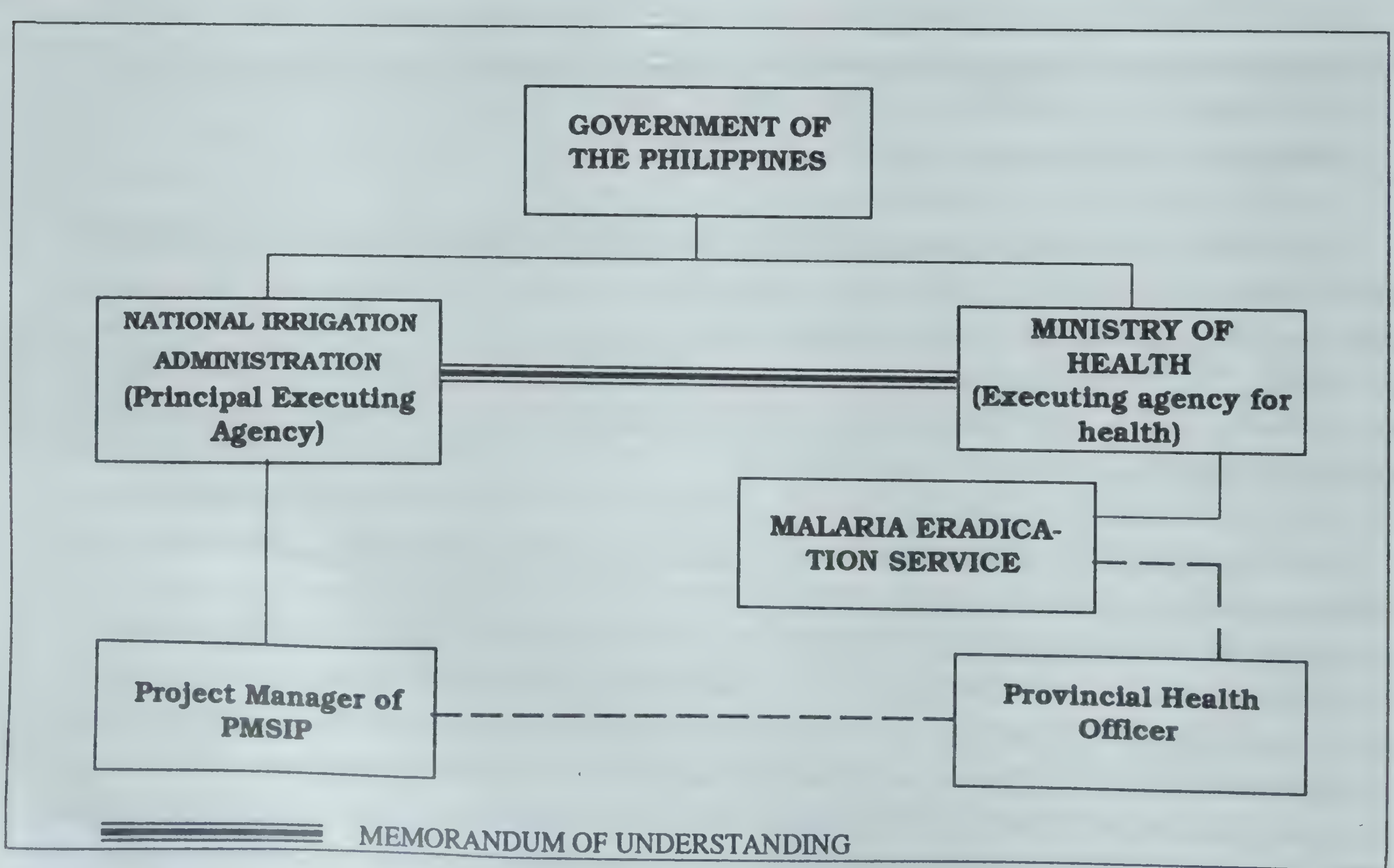


Figure 4. Present institutional structure for the implementation of a malaria control programme as a component of the Philippine Medium Scale Irrigation Project (OMSIP).

OTHER IRRIGATION RELATED ENVIRONMENTAL AND HEALTH CONSIDERATIONS

Environmental Impact Assessment

Irrigation projects, particularly those requiring the construction of dams and reservoirs, are among the most sensitive of all development projects due to the changes they may cause in the environment. While such projects are no doubt of importance to national economic development, all too often in the past their adverse impacts on the environment have not been taken into account at the project planning stage.

The need to assess the potential impacts of projects on the environment arose from the failure of traditional feasibility studies to capture and reflect the necessary resource and environmental factors into project planning. In the Philippines, environmental impact assessment gained impetus after the enactment into law of the Philippine environmental policy decree (Presidential Decree No. 1151). Section 4 of this decree stipulates that project proponents, whether from the public or private sectors, shall prepare, file and include in every action, project or undertaking which significantly affects the quality of the environment a detailed statement on: the environmental impact of the proposed action, project or undertaking; any degree of environmental effect which cannot be avoided should the proposal be implemented; an alternative to the proposed action; a determination that the short-term uses of the resources of the environmental are consistent with maintenance and enhancement of the long term productivity of the same; and whenever a proposal involves the use of depletable or non-renewable resources, a finding must be made that such use and commitment are warranted.

The rules and regulations implementing Presidential Decree No.1151 became effective in June 1978. The all-encompassing coverage of development projects and the dearth of manpower or expertise to make the systems fully operational, however, characterized the requirement as rather ambitious for a developing country like the Philippines. In 1979, Presidential Decree No. 1586 scaled down the scope of coverage of the impact assessment system by specifying that only those projects or areas which are environmentally critical will automatically fall within the provisionof the environmental assessment requirements. Presidential Proclamation No. 2146, which was issued in 1981, identified three types of environmentally critical projects (i.e., infrastructure projects, heavy industries, and resource extractive industries) and twelve kinds of environmentally critical areas (e.g., waterbodies, recharge areas of acquifers, etc.).

Significant steps have already been taken towards establishing the institutional framework required in the implementation of the environmental impact assessment in water resource development projects. Since 1980, the various major agencies with a mandate in the water resource development sector in the Philippines have been meeting and have agreed on coordinating in this connection in their respective projects.

Actually, NIA normally assesses the environmental impacts of proposed foreign-assisted irrigation projects as required by the foreign financing institutions. The assessment procedure is, however, not as comprehensive as in the case of the environmental impact assessment required by the Philippine environmental policy. In compliance with this policy, NIA is strengthening its capability for conducting environmental impact assessment through training of selected agency personnel by an environmental adviser under a grant by the Australian Government.

The task of monitoring the implementation of the environmental impact assessment programmes in all development projects and the consequent review of their results are the responsibilities of the National Environmental Protection Council created by virtue of Presidential Decree No. 1121. The council is composed of the Minister of Human Settlement, as chairman; the Minister of Natural Resources as Executive Officer; and as members, the Presidential Assistant for Economic Development and Affairs, the Minister of Public Works and Highways, the Minister of Local Government and Community Development, the Minister of Trade and Industry, the Minister of Budget, the Minister of Energy, the Minister of National Defense, the Minister of the National Science and Technology Authority, the Deputy Chairman of the Human Settlements Regulatory Commission, the Commissioner of the National Pollution and Control Commission, and the Chairman of the Executive Committee of the Environmental Centre of the Philippines.

Water quality improvement programmes in existing irrigation systems

Concerned with the growing environmental problems associated with the degradation of the quality of irrigation water from rivers and creeks, the NIA has been employing measures to prevent the entry of pollutants to irrigation systems. In1979, NIA coordinated with the National Pollution Control Commission, the Bureau of Mines of the Ministry of Natural Resources, the Ministry of Agriculture and the different mining companies regarding mine tailings problems in some of the agency-operated irrigation systems. The NIA proposed several non-structural and structural control measures which were accepted by the different agencies involved. As regards other pollutants affecting irrigation systems, such as wastes from geothermal plants, food processing plants, etc., NIA coordinates with the National Pollution Control Commission and the concerned public and private entities regarding studies and measures for correcting the problems.

The NIA, in coordination with the Philippine Council for Agriculture and Resources Research and Development, is currently conducting a study on the extent of irrigation water pollution in national irrigation systems throughout the country. The study primarily aims to identify the sources and causes of irrigation water pollution and measures for their abatement as related to: mine tailings, agricultural chemicals, industrial and agricultural effluents, and erosion and sedimentation. With this study, NIA hopes to develop a coordinated programme of preventing the pollution of irrigation water in the country and consequently reducing the health and environmental hazards it poses to the communities in the irrigated areas.

CONCLUSIONS AND RECOMMENDATIONS

In the Philippines, environmental and health considerations are adequately included in the planning and design of irrigation development projects, and are reflected in concrete measures at the construction phase. The present institutional arrangements with NIA, MOH and MPWH as the principal agencies involved seem to be satisfactory, as demonstrated by the on-going foreign-assisted irrigation projects, at least during the planning, design and construction phases. Some problems, however, may arise upon project completion. Experience shows that drainage channels constructed as part of the schistosomiasis control programme in some of the irrigation projects are left unmaintained due to lack of funds. To prevent such a situation and to ensure the continuity of some important activities related to the control of schistosomiasis, particularly the maintenance of health infrastructure in the period beyond project implementation, it is very

important for the national government to give priority financing to such activities so as not to waste the important investments that have already been made. Stronger cooperation among the member agencies of the SCC in such cases is very important. A set-up wherein the MOH is involved even during project planning and packaging should improve further the implementation of the programmes.

The enactment into law in 1977 of the Philippine environmental policy contributed much to the incorporation of health and environmental safeguards in irrigation development projects planned and implemented after that time. Experience, however, shows that incorporation of health and environmental safeguards in irrigation projects without foreign assistance is very difficult. As a matter of fact, only projects with foreign assistance have a comprehensive health and environmental component. This is primarily due to unavailability of funds. To ensure the incorporation of health and environmental programmes particularly the control of vector-borne disease in all types of irrigation projects whether small or large and foreign-assisted or not, the Minister of Health should be made a member of the National Water Resources Council and the National Environmental Protection Council.

MEMORANDUM OF AGREEMENT

This Memorandum of Agreement entered into by and between:

***NATIONAL IRRIGATION ADMINISTRATION,** herein represented by ALFREDO L. JUINIO, with offices at E. de los Santos Avenue, Quezon City, hereinafter referred to as the NIA*

and

***MINISTRY OF HEALTH,** herein represented by CLEMENTE S. GATMAITAN, M.D., M.P.H. Minister with offices at San Lazaro Compound, Manila, hereinafter referred to as the MOH;*

-WITNESSETH-

WHEREAS, the Government through the National Irrigation Administration has programmed the implementation of the Second Davao del Norte Irrigation Project in Davao del Norte, Mindanao, with a bank loan from the Asian Development Bank, hereinafter referred to as the ADB;

WHEREAS, in the implementation of the project, the NIA, being the project proponent is agreed to be the principal executing agency and the MOH, as the executing agency for Public Health;

WHEREAS, there is a need for a coordinative effort between the NIA and the MOH to effectively carry out the implementation of the project;

NOW, THEREFORE, for and in consideration of the foregoing premises, the parties hereby agree as follows:

I. OBLIGATIONS OF NIA

1. In coordination with the MOH, to plan, design and construct the necessary drainage works to achieve the objective of the schistosomiasis control.

2. To provide financing for the foreign currency requirement for the implementation of the health services and schistosomiasis control programme in the project, out of the loan proceeds obtained from the ADB.

3. Procure, on behalf of the MOH, the necessary laboratory equipment such as microscope, vehicles, etc., and necessary drugs and chemicals reimbursable from and to the extent of the loan proceeds allocated to MOH, to effectively carry out the project.

4. NIA shall turn over to MOH the equipment, vehicles, and drugs purchased under the loan and such equipment and vehicles shall eventually become MOH property upon completion of the project.

5. Provide reasonable incentive/honorarium in accordance with the rates approved by NIA to appropriate number of personnel to be fielded by MOH who will be actually involved in the schistosomiasis prevention and control within the project area to the extent that such incentives shall be allowed only during the prosecution and up to the completion of the Second Davao del Norte Irrigation Project.

6. Provide technical assistance for the construction of the necessary health infrastructure and facilities like rural health centers, for the effective performance of the MOH personnel in their assigned tasks.

II. OBLIGATIONS OF MOH

1. MOH shall prepare and submit to ADB, in consultation with NIA, a detailed implementation plan for the health component of the project and assist or advise NIA in the preparation of its plans for drainage and for the operation and maintenance of canals in the project area in order to increase their impact on schistosomiasis control.

2. Provide financing for the local currency requirement of the health component including the construction of health infraStructures and facilities, out of its budget over the implementation period of about five years.

3. Provide for the assignment of necessary personnel with adequate pecuniary and other incentives to assure the participation of sufficient personnel as well as to execute and complete the construction of health infrastructures required to meet the health service needs of the population in the project area.

4. Provide repair and maintenance services to the health infrastructures constructed including equipment and vehicles procured through this project, out of its own fund.

5. Continue to provide personnel, equipment, and drugs and chemicals as necessary for general rural health care in the project area after project completion.

IN WITNESS WHEREOF, the parties hereto have set their signatures this day of 1978.

(SGD.) CLEMENTE S. GATMAITAN
Minister
Ministry of Health

(SGD.) ALFREDO L. JUNIO
Administrator
National Irrigation Administration

MEMORANDUM OF AGREEMENT

This Memorandum of Agreement entered into by and between:

*The **NATIONAL IRRIGATION ADMINISTRATION** represented by FIORELLO R. ESTUAR, Administrator, with offices at E. de los Santos Avenue, Government Center, Quezon City, hereinafter referred to as the NIA;*

and

*The **MINISTRY OF PUBLIC WORKS & HIGHWAYS** represented by JESUS S. HIPOLITO, Minister, with offices at Bonifacio Drive, Port Area, Manila, hereinafter referred to as the MPWH.*

-WITNESSETH-

WHEREAS, the Philippine Government through the National Irrigation Administration has programmed the implementation of the Third Davao Irrigation Project in the province of Davao del Norte with a loan from the Asian Development Bank, hereinafter referred to as the ADB;

WHEREAS, the said loan has been provided on the terms and conditions stipulated in the Loan Agreement dated 3 November 1982 between the Republic of the Philippines and the Asian Development Bank;

WHEREAS, in the implementation of the project, the NIA being the project proponent has agreed to be the Principal Executing Agency, and the MPWH as the Executing Agency for Rural Water Supply System Component;

WHEREAS, there is a need for a coordinative effort between the NIA & the MPWH to effectively carry out the implementation of the project.

NOW, THEREFORE, for and in consideration of the foregoing premises, the parties hereby agree as follows:

I. OBLIGATIONS OF MPWH:

1. In accordance with the provisions of Schedule 1 & 6 of the Loan Agreement, MPWH shall, in coordination with NIA, be responsible for the construction of approximately two hundred seventy four (274) units of Level I tubewells for installation in about 51 Barangays; construction of approximately 1050 Level I shallow wells for installation in the schistosomiasis endemic parts of the project; and construction of two (2) units of Level II systems for Nabunturan Poblacion at depths ranging from 30 m to 100 m.

2. MPWH shall submit to the Bank for approval, within three (3) months of the Effective Date of the Loan, a detailed implementation plan, including site selection, construction schedule and schedule for procurement of necessary equipment for the implementation of Rural Water Supply System Component of the project.

3. In accordance with Section 6, Schedule 6 of the Loan Agreement, MPWH shall establish a suitably staffed Project Office at Tagum within three (3) months of the Effective Date of the Loan. This project office shall be headed by an Officer-in-Charge. The Officer-in-Charge shall coordinate with the NIA Project Manager on matters concerning the project.

4. MPWH shall be responsible for the procurement of the equipment and materials necessary for the implementation of the Rural Water Supply of the project. Such procurement shall be carried out in accordance with the procedures set forth in Schedule 4 of the Loan Agreement.

5. MPWH shall be responsible for providing the local currency requirements of the Rural Water Supply System which shall be included in its yearly budgets covering the implementation period of the project and to assure that such funds shall be made available as and when needed to ensure the successful implementation of the project.

6. MPWH shall maintain a separate record and account adequate to identify the goods and services financed out of the proceeds of the loan, to disclose the use thereof in the project, to record the progress and cost of the project and to reflect in accordance with consistently maintained sound accounting practices the operation and financial condition relevant to the implementation of the Rural Water Supply System component. These accounts will be audited annually, in accordance with sound auditing principles, by auditors acceptable to the Bank and certified copies of the audited accounts and the auditor's reports will be furnished to the Bank within six (6) months after the end of each fiscal year.

7. All applications for withdrawal of loan proceeds from the loan account for the purpose of financing expenditures on the Rural Water Supply System of the project shall be made through NIA. MPWH shall be responsible for the preparation of all the necessary supporting documents. MPWH shall ensure that all goods financed out of such proceeds are used exclusively in carrying out the agency's respective components.

8. Pursuant to the provisions of Schedule 5 of the Loan Agreement, MPWH shall in coordination with NIA, be responsible in hiring and engaging the Consultant required for the implementation of Rural Water Supply Systems of the project.

9. Pursuant to the provisions of Section 17, Schedule 6 of the Loan Agreement, MPWH, through its Provincial Office and the Rural Water Works Development Corporation, shall organize water users' groups in the project area and provide assistance to these groups in the operation and maintenance of the water supply systems in the Project Area.

II. OBLIGATIONS OF NIA

1. NIA shall provide assistance, as may be needed, in the implementation of the procedures to be followed relative to procurement of the equipment and materials for the rural water supply system of the project. Such procurement shall be carried out in accordance with the procedures set forth in Schedule 4 of the Loan Agreement.

2. For the purpose of withdrawal from the Loan proceeds, NIA shall be responsible for the submittal of the applications to ADB for financing of expenditures on the Rural Water Supply System. NIA shall ensure that all goods financed out of such proceeds are used exclusively in carrying out the agency's respective components.

3. NIA shall provide coordination and other technical assistance as may be needed in the execution of the portion of the project for which MPWH is responsible.

IN WITNESS WHEREOF, the parties hereto have set their signatures this 1st day of February 1983.

(SGD.) JESUS S. HIPOLITO	*(SGD.) FIORELLO R. ESTUAR*
Minister	*Administrator*
Ministry of Public Works & Highways	*National IrrigationAdministration*

MEMORANDUM OF AGREEMENT

This AGREEMENT made and entered into this day of June 1980 at Diliman, Quezon City. Metro Manila by and between:

*The **NATIONAL IRRIGATION ADMINISTRATION**, with principal office at E. de los Santos Avenue, Diliman, Quezon City, represented herein by the Administrator, FIORELLO R. Estuar, hereinafter referred to as NIA;*

and

*The **MINISTRY OF HEALTH**, with principal office at San Lazaro Compound, Sta. Cruz, Manila, represented herein by the Minister, ENRIQUE M. Garcia, hereinafter referred to as MOH;*

- WITNESSETH-

WHEREAS, the World Bank has granted the NIA on 29 March 1980 a US$ 71.0 M loan to partially finance the Philippine Medium Scale Irrigation Project which would provide for the construction of irrigation facilities to benefit some 38 000 hectares of riceland in the Provinces of Oriental Mindoro, Occidental Mindoro and Palawan;

WHEREAS, the strengthening of the Malaria Control Unit in Palawan is an integral component of the project;

WHEREAS, the project envisages a provision of US$ 400 000 to strengthen the anti-malaria campaign in Palawan specifically in the Municipalities of Aborlan and Narra where the Malatgao and Batang-Batang River Irrigation Projects are situated;

WHEREAS, the Malaria Eradication Service of the MOH which is responsible for monitoring and control of the disease in the affected area would direct the program under the project;

WHEREAS, provision would be made under the project for an information campaign to alert the population to the dangers of the disease and supply information on prevention and treatment;

WHEREAS, the NIA and MOH must enter into an agreement acceptable to the World Bank by 31 December 1980, for the implementation of the malarial control component of the Project;

WHEREAS, the NIA will commence with the implementation of the Philippine Medium Scale Irrigation Project on 1 July 1980;

NOW, THEREFORE, for an in consideration of the terms and conditions set forth, the parties have agreed as follows:

I. Project Personnel

1. Considering the limited tenure of five years and the location of the project, it would be difficult for MOH to attract qualified personnel at the government civil service salaries and to overcome this problem, the Malaria Control Team personnel below the zone chief category would be employed and paid by NIA based on the following NIA standard position and qualification and would be detailed to MOH:

	NIA Equivalent	
a. Sector Chief	*Const. Foreman*	*College Graduate*
b. Med. Lab. Tech.	*Lab. Technician*	*College Graduate*
c. Squad Leader	*Leadman*	*High Sch. Graduate*
d. Driver	*Driver*	*(Complete primary grades)*

2. That while on detail, all personnel will be under the administrative control and technical supervision of the MOH.

3. That personnel from zone chief category and above who will be engaged in the implementation of the program would be paid by MOH, however, NIA would provide honoraria which would be fixed by the Director, MES, MOH and NIA Project Manager.

4. That the recruitment and fielding of personnel would be made in time for the 1 July 1980 start of the activities.

II. Disbursement of Fund

5. Payment of salaries, wages, honoraria and travelling expenses of aforecited personnel will be made through the NIA disbursing officer after approval of MOH and NIA officer. The NIA officer will see to it that expenditures are properly costed. Semi- annual and annual reports of disbursement would be made available for evaluation.

III. Procurement of Equipment, Supplies and Materials

6. Procurement of all equipment, supplies and materials would be made through the NIA. MOH would program the uses and submit to NIA requisition and issue voucher in due time.

IV. Use of Vehicle and Equipment

7. Vehicles and equipment would continue to be used by MOH after the project completion or during the operation and maintenance phase of the irrigation system. Memorandum receipt of all items turned over to MOH would be prepared.

8. Since project implementation will start on 1 July 1980 when vehicles, equipment, supplies and materials are still in the procurement process, MOH would furnish priority requirements needed to be replaced when procured stock will be available.

9. That NIA would provide the requirements for fuel and oil, maintenance and minor repairs of the vehicle duly assigned by MOH as stipulated in Item IB-8 of this agreement, based on the NIA rules and regulations in the control of the usage of vehicle.

V. Monitoring and Reporting

10. MOH would furnish NIA a program of work picturing target quantities and work schedules as well as materials and supplies needed. In case a revision of the plan has been made, a revised program should be furnished. The implementation schedule in the form of a bar chart would be very helpful.

11. A monthly status report of activities and accomplishments would be furnished by MOH to NIA.

12. Communications to NIA pertaining to project implementation should be addressed to the Project Manager, Philippine Medium Scale Irrigation Project, and to the Director, Malaria Eradication Service for the MOH and that communications at the provincial level or the project area should be addressed to the Unit Chief, MES, Puerto Princesa, Palawan, for MOH and to the Division Chief of NIA at Narra, Palawan.

VI. Mutual Requirement

13. That both parties would designate project coordinators to facilitate monitoring of project activities.

14. That NIA and MOH shall regularly inform each other on the latest development concerning the project.

15. That this agreement may be modified any time upon subsequent written agreement between the parties.

In witness whereof, the parties have hereunto set their hands and seal this day of June 1980 at Quezon City, Metro Manila, Philippines.

NATIONAL IRRIGATION ADMINISTRATION	*MINISTRY OF HEALTH*
(SGD.) FIORELLO R. ESTUAR *Acting Administrator*	*(SGD:) ENRIQUE M. GARCIA* *Minister*

INSTITUTIONAL ARRANGEMENTS TO ENSURE THE INCORPORATION OF HEALTH AND ENVIRONMENTAL SAFE-GUARDS IN WATER RESOURCE DEVELOPMENT PROJECTS - THE MAHAWELI DEVELOPMENT PROGRAMME, SRI LANKA -

by

Lalit Godamunne

THE MAHAWELI DEVELOPMENT PROGRAMME

The development of the irrigation potential of the Mahaweli river is crucial for the further development of agriculture in Sri Lanka. Not only is the river the longest in the country, but it flows through the intermediate and dry zones which encompass two-thirds of the land area. Investigations have therefore been conducted as early as the 1950s, often with the help of international agencies and foreign governments, with a view to developing the irrigation and hydropower potential of theMahaweli river and its tributories.

Irrigation facilities are a prerequisite for the development of farming activities in the intermediate and dry zones, for, although these areas receive a substantial volume of rainfall in the major monsoon season, they are characterized by dry weather and drought for the greater part of the year. The provision of irrigation facilities benefits farmers in these areas and also enables the resettlement of farmers from other parts of the country. Although most farming families are presently residential in the wet zone, their farms are to a large extent economically not viable due to the fragmentation of holdings and the limited availability of supplementary employment opportunities in the wet zone.

A Master Plan for the development of the irrigation and hydropower potential of the Mahaweli and its tributories was drawn up by the UNDP and the FAO in 1968 and many of the detailed plans made subsequently are set within the framework for development proposed in that report. The UNDP & FAO study envisaged the development of 360,000 hectares of land in the Mahaweli and adjacent basins (including 98,400 hectares of existing agricultural lands) and the production of 508 MW of hydropower. The programme was envisaged to be completed in 30 years. Work on the first project under the Mahaweli Development Programme began in 1972.

The present government, which assumed office in 1977, decided to implement the basic Mahaweli Development Programme on an accelerated basis. The Accelerated Programme aimed to irrigate 120,000 hectares of new land and to generate 470 MW of hydro-power. At the time the new government assumed office, the unemployment rate of the country's workforce was estimated at 20%. The Accelerated Programme was expected to provide substantial new employment opportunities in both the agriculture and construction sectors. The anticipated increase in domestic food production which would help save on the country's foreign exchange expenditures also weighed heavily with the decision makers at the time. Furthermore, since the present government assumed office, an increase in the demand for power occurred in an unprecedented way and it became necessary to step up the power generation from domestic sources to contain the outflow of funds for the import of fossil fuels.

Mr Godamunne is Secretary General of the Mahaweli Authority, based in Colombo, Sri Lanka.

The various components of the Accelerated Programme with respect to the irrigation of agricultural land, settlement of farm families, and the generation of hydropower are shown in tables 1 and 2 below. The accompanying map (figure 1) shows the location and extent of land areas to be developed and also the location of the major reservoirs which are to be constructed. In total, 112,000 farming families comprising about 600,000 persons are expected to benefit from settlement on newly irrigated lands. Irrigation facilities available on lands farmed by another 14,000 families will also be augmented under the Accelerated Programme.

Several foreign governments and UN agencies have made available financial assistance for both headworks and downstream development.

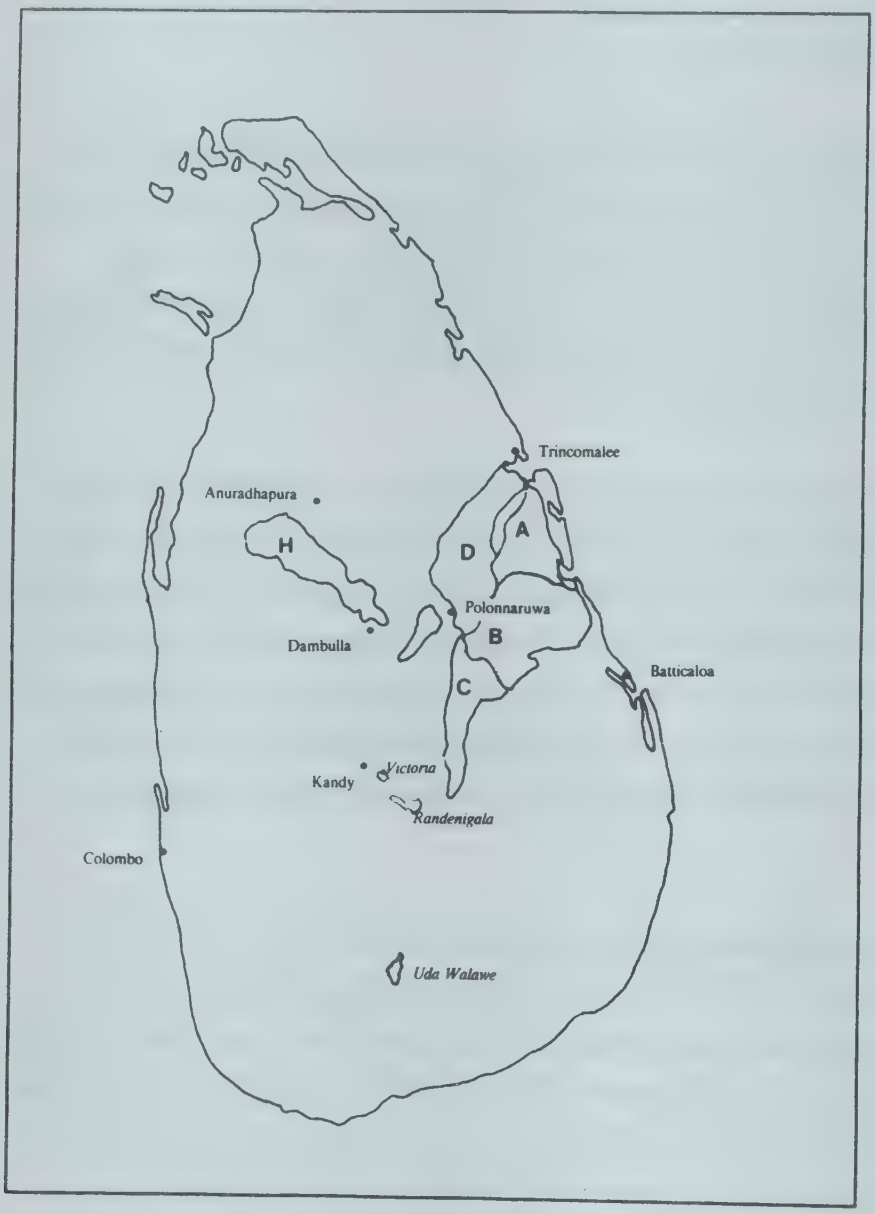


Figure 1. The various components (systems) of the Accelerated Mahaweli Programme area.

ADMINISTRATIVE ARRANGEMENTS FOR THE IMPLEMENTATION OF THE MAHAWELI DEVELOPMENT PROGRAMME

The implementation of the Mahaweli Development Programme was begun in 1978 by the Ministry of Mahaweli Development. However, it soon became evident that the administrative procedures of a government ministry were less than ideal for the implementation of a development programme of that size on an accelerated basis. Therefore, in 1979, the Mahaweli Authority, a government corporation, was set up by an Act of Parliament with the responsiblity for the implementation of the Mahaweli Ganga Development Programme.

The Act by which the Mahaweli Authority was set up firstly provided for the Minister in

charge of the Mahaweli Development Programme, with the approval of the President, to declare any area which could be developed with the water resources of the Mahaweli Ganga or any other major river as a "special area" in relation to which the Authority could exercise all or any of its powers, duties and functions.

The functions of the Authority in relation these special areas were designated in the Act as comprising

- Planning and implementation of the Mahaweli Ganga Development Scheme including the construction and operation of reservoirs, irrigation distribution systems and installations for the generation and supply of electric energy.

- Fostering and securing the full and integrated development of any Special Area.

- Optimising agricultural productivity and employment potential and generating and securing economic and agricultural development within any Special Area.

- Conserving and maintaining the physical environment within any Special Area.

- Furthering the general welfare and cultural progress of the community within any Special Area.

- Promoting and securing the participation of private capital, both internal and external, in the economic and agricultural development of any Special Area.

- Promoting and securing the cooperation of Government departments, State institutions, local authorities, public corporations and other persons, whether private or public, in the planning and implementation of the Mahaweli Ganga Development Scheme and in the development of any Special Area.

The powers of the Mahaweli Authority include, *inter alia* , (a) construction, maintenance and operation of dams, channels, drainage systems and other irrigation works and structures for the purpose of achieving its objectives; (b) construction of such hydro-power installations as may be necessary for the purpose of the generation and supply of electric energy; (c) taking such measures as may be necessary for watershed management and control of soil erosion; (d) promoting and assisting in the settlement of persons on lands, farms and properties in any Special Area, and paying for, contributing to the expenses of or in other ways assisting persons settling, farming or otherwise developing lands, farms and properties in Special Areas; (e) providing advisory and farmer training services to improve cultivation techniques, water management, soil management and preservation of the physical environment; (f) managing and operating a scheme of supervised credit to farmers; (g) providing agricultural inputs to farmers; (h) carrying out research related to the development of agriculture and agro-based or related industries; (i) promoting, undertaking and participating in agro-based or related industrial or commercial enterprises, and (j) providing marketing services for the purchase, storage, processing and sale of farm and other produce.

The Act by which the Mahaweli Authority was set up also provides for the Authority to give special or general direction to specified Government Departments and Corporations requiring these entities to perform any functions and duties as deemed necessary by the Authority in any

Table 1. Accelerated Mahaweli Programme - development of Agricultural and Settlement

System	Net Irrigable Areas Gross area (ha.)	Existing areas improved (ha)	New areas (ha)	Target number of farm families	Progress of settlement as at 31.3.84	Total capital costs*
A	106 000	Nil	14 000	14 000	Nil	Not available
B	135 000	1 506	40 420	35 690	2 790	7 055
C	66 000	4 070	22 800	20 370	7 520	3 746
D	61 000	Nil	15 340	15 300	Nil	Not available
G	6 324	2 180	2 990	2 950	1 210	256
H	43 000	6 570	23 480	23 480	22 770	1 895

*in millions of Sri Lankan rupees
(exchange rate at the time: approx. 1US$ = 25 rupees)

Source: Mahaweli Authority and MEA

Table 2. Accelerated Mahaweli Programme power generation

Reservoir & Headworks	Date of Completion	Gross storage (m.cu.m.)	Power generation (MW)	Total capital cost*	Foreign concessional funding*
Victoria	1984	728.0	210	7983.7	4647.1
Kotmale	1984	174.0	134	8755.0	6031.0
Maduru Oya	1983	586.5	7.5	2631.3	1441.8
Randenigala	1985	860.0	126	4450.1	3567.7

*in millions of Sri Lankan rupees
(exchange rate at the time: approx. 1US$ = 25 rupees)

Source: Mahaweli Authority

of the special areas. The Mahaweli Authority can, furthermore, establish departments or agencies under its control for the purpose of discharging any of its functions. Making use of this provision the Mahaweli Economic Agency was set up in 1981 to take charge of settlement and post-settlement activities such as agricultural development in the Mahaweli areas. From the in-

ception of the Mahaweli Development Programme, the Mahaweli Development Board (now the Mahaweli Engineering and Construction Agency) had been in charge both of the construction and settlement activities in the downstream areas. However, with the institution of the Accelerated Programme in the late 1970s it was felt that the resources of the MDB would be inadequate to undertake the increased workload with respect to the supervision of the settlement and development of these areas, since that organization was heavily oriented towards engineering activities. MECA's construction work and supervision of construction in the downstream areas includes not only the irrigation and drainage network, but also roads, social infrastructure facilities such as schools and hospitals, and administrative buildings for government agencies and housing for the staff of the Mahaweli Authority. Therefore, the Mahaweli Economic Agency (MEA) is responsible today for settlement and post-settlement management in the downstream areas. The administrative arrangements for the delivery of health care facilities in the Mahaweli areas and for dealing with matters pertaining to the environment devolves on the MEA, and the arrangements are specified below in the relevant sections.

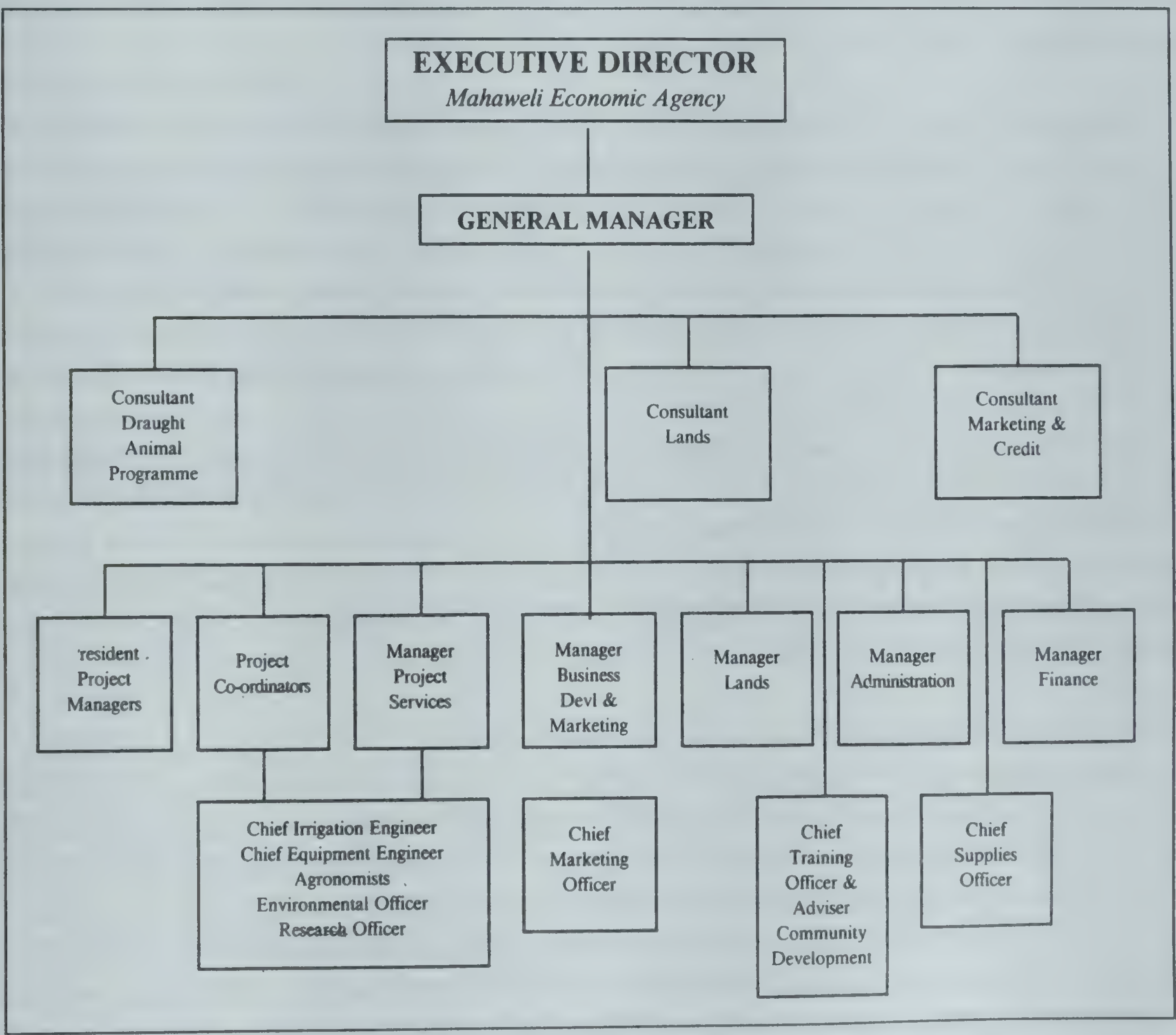


Figure 2. Organizational sturcture of the Mahaweli Economic Authority (MEA) at headquarters level.

INSTITUTIONAL ARRANGEMENTS FOR HEALTH CARE DELIVERY TO THE INHABITANTS OF THE MAHAWELI AREAS.

The Ministry of Health has primary responsibility for delivery of both the preventive and curative health services to the entire country, including the Mahaweli areas. The institutional

arrangements of the Ministry for the health care delivery system are uniform in all areas of the country.

In 1980 the Government of Sri Lanka signed the Charter for Health Development with the WHO and thereby endorsed the concept of Health for All by the Year 2000. The key approach adopted in Sri Lanka to achieve this goal is that of primary health care. The health care delivery system which prevailed in the country until 1980 is being modified to take account of the requirements of primary health care. For the next two decades, the health care system will aim at (a) the establishment of a number of grass-roots level Gramodaya Health Centres - one for every 3000 people - to ensure that essential health care is available to all close to their homes; (b) the strengthening of the network of higher-level health units so as to ensure logistic, supervisory and referral support to the Gramodaya Health Centres: (c) the promotion of community participation with respect to matters both of health and sanitation; and, (d) the gradual functional integration of curative and preventive care, with emphasis on the preventive component. The benefits of primary health care will accrue to settlers in the Mahaweli areas as much as to persons residing in other rural areas of the country.

It is necessary to adopt the tenets of primary health care, since in Sri Lanka numerous illnesses, many hospital admissions, and even a significant number of deaths are attributable to preventible causes stemming largely from environmental contamination. This is equally true of the Mahaweli areas as of other areas of the country. In tables 3 and 4 morbidity and mortality patterns by different diseases for Sri Lanka (1982) are shown as a whole and for the Anuradhapura SHS area under the Matale SHS area in which the greater part of the H area of the Mahaweli Development Programme is located. The high incidence of intestinal infections and helminthiasis in the Anuradhapura SHS area (as much as in the rest of the island) should be noted, together with the importance of deaths due to intestinal infections. Morbidity and mortality in Sri Lanka are closely related to malnutrition. Table 3 shows that the incidence of anaemia in the Anuradhapura district is three times as high as in the island as a whole. This is at least partly attributable to the fact that settlement was taking place in the Mahaweli H area in 1982, frequently of persons from amongst the poorest sections of the population. These poor persons will directly benefit from the Accelerated Mahaweli Development Programme.

As mentioned above with respect to the Mahaweli agencies, the MEA is responsible for health care delivery in the downstream areas. The MEA has, in a very useful manner, supplemented the efforts of the Ministry of Health with respect to the delivery of preventive and curative services, including health education. The Ministry of Health has nominated a Deputy Director to liaise with the Mahaweli agencies regarding health care delivery. The MEA is mainly dealing with this officer concerning matters pertaining to the contruction of health infrastructure facilities and the assignment of health personnel to the Mahaweli areas. A standing committee on health manned by representatives of the MEA, MECA and the Ministry of Health meets periodically to resolve outstanding issues.

It is in the context of morbidity and mortality patterns due to preventible diseases in the Mahaweli areas, that the health education programmes of the MEA take on significance, since they are geared to familiarize settlers and their families with the basic requirements for staying healthy. The structuring of these programmes, which are designed to utilize volunteers residing in the Mahaweli areas themselves also fits in with an important aim of primary health care, i.e. mobilizing the energy and enthusiasm of community members in the task of ensuring the com-

munity's health. The Ministry of Health provides its share of inputs into the education programmes in the Mahaweli areas through training provided to MEA staff and health volunteers, and through other education programmes conducted directly by the Ministry.

Table 3. Morbidity per 100,000 of the population (1982)

	Sri Lanka	S.H.S. Matale	S.H.S. Anuradhapura
Intestinal Infections	1100.4	1009	863.6
Tuberculosis	76.3	34	76.4
Poliomyelitis	0.7	-	2.4
Helminthiases	171.8	313	225.0
Malignancies	106.2	88	35.5
Nutritional Deficiencies	124.9	92	67.2
Anaemia	330.7	755	940.2
Hypertenion and Ischemic Heart Disease	337.0	364	469.8
Abortions	222.1	156	223.8
Normal deliveries	1985.7	2225	2063.7
Ill-defined cases	1295.7	1064	942.2
Injury and poisoning	1729.7	1506	1737.1

Source: Ministry of Health, Colombo

Table 4. Mortality per 100,000 of the population (1982).

	Sri Lanka	S.H.S. Div. Matale	S.H.S. Div. Anuradhapura
Intestinal Infections	11.8	13.1	11.4
Tuberculosis	4.1	1.1	3.4
Poliomyelitis	0.0	-	0.1
Helminthiases	0.5	0.2	0.2
Malignancies	7.1	2.2	2.7
Nutritional Deficiencies	1.3	1.5	0.9
Anaemia	3.0	2.6	1.9
Hypertension & Ischamic Ht. Dis	20.0	9.0	19.7
Abortions	0.1	-	-
Normal deliveries	1.0	10.0	-
Ill-defined cases	12.2	2.6	2.9
Injury and poisoning	23.4	26.8	22.0

Source: Ministry of Health, Colombo

The MEA appoints one health volunteer to every 25 families in the Mahaweli areas. The volunteers, who are young men and women, are appointed in consultation with the communities they will serve. The health education programmes of the MEA are delivered by these volun-

teers. They are trained by the Health Education Bureau of the Ministry of Health and are supervised by the Community Development Officers of the MEA. The system of health volunteers has been functional in the H area for many years and volunteers are now being trained in the newer Mahaweli Systems such as B and C.

An important function performed by the health volunteers is education of the settlers and their families in the control of malaria. Malaria is endemic to the dry zone, and in combination with the fact that many new settlers come from non-malarious areas and have therefore not developed any immunity to the disease, malaria tends to have a very high incidence in the Mahaweli areas. Health volunteers also disseminate information on proper sanitation and waste disposal methods which help to reduce the incidence of a number of diseases.

With respect to the curative aspects, the health volunteers are provided with simple medications which they are taught to dispense as required. These medications include drugs for the prevention and treatment of malaria.

The nutrition education programme is another important facet of the health education work undertaken by the MEA. In most cases a separate set of volunteers are recruited to staff this programme. The volunteers are trained by the Ministry of Health and the MEA. Information is disseminated by the volunteers with respect to general nutrition, infant and child nutrition, and nutritional requirements duringpregnancy and lactation. A nutrition supplement, ''thriposha'' is also prepared and distributed by these volunteers at one-site feeding centres to children below 5 yearsof age and to pregnant and lactating women. It is estimated that the supplement provides a significant proportion of the daily calory requirements and all of the protein requirements of these categories of persons. The nutrition education programme is again well established in the H area. The implementation of the programme in the other Mahaweli areas is just beginning. Nutrition volunteers are now being trained in Systems B and C.

A series of courses for young women who have left school, including courses on health and sanitation, are conducted at the Home Development Centres which are located in the H area. The participants are awarded a certificate on the successful completion of the course, which is free of charge.

With respect to the services provided by the MEA in areas of preventive and curative health services, mention should be made of programmes designed to ensure safe drinking water supply, proper sanitation and again, nutrition supplementation. Programmes to control malaria, eliminate helminthiasis, ensure immunization of children and those designed to diagnose and treat anaemia are the responsibility of the Ministry of Health. The health education programmes of the MEA have, however, helped to make the programmes of the Ministry of Health much more effective.

Since 1981 the MEA has implemented its own programme for the construction of wells which supply water for household use. Much of MECA's earlier construction programme for large wells (1 for every 20 families) in the Mahaweli areas was found to be unsatisfactory. The new programme therefore aims to construct 1 well for every 6 families. Of the target number in the H area of 4040 wells, 2045 have been constructed. In addition, 1,954 wells have been constructed in the other areas. A construction programme for deep wells funded by UNICEF has been implemented from 1983 in areas where shallow wells are not suitable. Of the 80 deep wells targetted for the H area 20 have been constructed, and 14 deep wells have been constructed in other areas.

A self-help latrine construction programme is under implementation in all Mahaweli areas through the MEA. Under this programme materials to construct a simple latrine are provided together with a cash grant of Rs. 250/-. Of the construction target of 24,000 latrines in the H area 10,335 have been constructed. In other areas 6,923 latrines have been constructed. Problems encountered with this programme relate not to construction but to the maintenance and use of the latrines once they are constructed, for traditionally the settlers are not oriented to the use of latrines. The health education programme of the MEA is making a serious attempt to induce the settlers to use these latrines in order to ensure less environmental contamination and better health for themselves.

The MEA has also initiated a system of medical services in zones 2 to 6 of System C. The Ministry of Health was unable to service these settlers due to a shortage of staff. The MEA therefore organized for these areas the services of a full-time medical officer and volunteer doctors. The expenditures incurred in these areas is fully financed by the Mahaweli Authority.

The Mahaweli Authority has been instrumental in arranging for assistance from the World Food Programme for the Mahaweli settlers in the initial 15 months of settlement. The food ration which is distributed weekly to the settler families consists of wheat, flour, sugar, pulses, milk foods and dried fish, and provides a large part of the food requirements of these families.

Polyclinics operated by the Ministry of Health provide the requirements of the Mahaweli settlers with respect to weighing of infants, immunizations, elimination of helminthiases, care of pregnant and lactating mothers, and diagnosis of anaemia amongst others. The MEA supports these programmes in various ways.

A programme to spray the homes of settlers and Mahaweli officers against mosquitoes is operated by the Ministry of Health. This is another area in which health education has been found to be of great importance. The settlers are normally unwilling to have their houses sprayed with malathion due to its unpleasant smell and therefore tend to resist spraying. This resistance can only be broken by creating a greater awareness of the benefits of the anti-malaria programme. Until now the programme has not been supervised by the Mahaweli agencies but due to its limited acceptance the MEA plans to enforce supervision of the spraying programme as from the latter part of 1984.

ENVIRONMENTAL PROBLEMS AND REMEDIAL MEASURES

At the present time, the Mahaweli Authority through the MEA deals with environmental problems in the Mahaweli areas. Although the government set up the Central Environment Authority in 1980, its involvement in activities in the Mahaweli areas is still minimal. The Mahaweli Authority has been concerned with the possible adverse environmental impacts of the Mahaweli Development Programme, and has sought expert advice on ways and means to mitigate these impacts. The feasibility reports commissioned for the different Mahaweli systems include an assessment of the possible environmental impact of each of these systems. In addition, in 1980, the government commissioned a special study aimed at investigating the possible impact of the Accelerated Programme on the terrestrial, aquatic, and human environments. In 1981, in the light of the findings of this study, MASL drew up an environmental action plan.

The action plan set out an interim set of planning guidelines with respect to forestry planning and management, watershed management, wildlife conservation, water resources research and monitoring, fisheries development, health care and sanitation planning, water and soil management, and land use planning. The agencies who would be responsible for implementing the components of the plan and the source of funding for many of the programmes were also identified.

In 1981 MASL set up a Technical Sub-Committee on Forestry with the participation of the Forest Department, the State Timber Corporation, the Ministry of Lands and Land Development, and the Department of Wild Life Conservation. This committee provides technical guidance and advice on the forestry programmes in the downstream areas and the management of watersheds. In 1982, a Technical Committee on the Environment was set up by MASL with representation from various governmental and non-governmental organizations connected with environmental conservation, to advise MASL on its action plan and other matters pertaining to the environment. The Central Environmental Authority is a member of the Technical Committee on Enviroment. An environment unit has also been set up within the MEA with the primary function of coordinating the planning, implementation and monitoring of environmental aspects pertaining to the Mahaweli areas. In 1983 MASL set up a Sub-Committee on Environmental Education to disseminate information on environmental matters amongst the Mahaweli settlers.

Much of the work of the Mahaweli Authority and of the MEA has until now been concentrated in the areas of forest conservation, replanting of forest, and wildlife conservation. These activities are briefly described below.

Forestry Resources in Downstream Areas

Only about 28% of the gross land area under the purview of the Accelerated Mahaweli Programme is under forest or jungle cover. Large extents of forest were being cleared illicitly in a wasteful manner, for timber and as a result of the encroachment by people wishing to stake a title to land in the area. By 1980 logging operations had been extended into areas for which detailed land use maps had not yet been prepared. The consequence was that more land was being cleared than was likely to be required for settlement and cultivation.

At the same time, the importance of fuel wood plantations to the economy of the settlers was recognized. On realistic consumption norms it was estimated that the firewood then available in the Mahaweli areas would suffice for the anticipated population at full development only for 2-3 years. It was therefore necessary to conserve the existing forest cover in downstream areas and to rapidly reforest non-arable lands with quick-yielding firewood varieties. In the alternative, the settlers would be forced to resort to the use of kerosene, the calorie cost of which is about ten times that of firewood, and whose use would also entail higher outlays by the government on subsidies, since the consumption of kerosene by poor households is presently subsidized.

To endorse a programme of forest conservation and replanting a much greater number of forest rangers would be required, and therefore recruitment of rangers by the Forest Department was to be increased and training activities stepped up.

Controlled clearing of forest in the downstream areas was put into effect from 1981. The procedure adopted was for the Physical Planning Unit of MASL to specify areas suitable for

settlement and cultivation in the systems being implemented to theTechnical Sub-Committee on Forestry. The Sub-Committee in turn indicated to the State Timber Corporation the areas where logging was allowed and undertook itself the task of monitoring the progress of the logging operations.

The Physical Planning Unit of MASL also identified, in the systems being implemented, lands suitable for development in forest and notified its decisions to the Forest Departement. The Forest Department then went ahead with its programme of reforestation which comprised the establishment of demonstration plots close to settlement hamlets (villages), the establishment of nurseries in the different systems, provision of fertilizer and trees, and the allocation of forest development blocks to settlers to be planted with quick yielding firewood varieties and useful types of timber. In the meantime, the Forest Department on its own planted trees to act as windbreaks, and also for soil conservation purposes.

MASL has also organized a reforestation programme within a radius of 1 mile from either bank of the Minipe Right Bank Canal. The programme is being implemented through a non-governmental organization. The Mahaweli Authority has organized this programme since the resources of the Forest Department are inadequate to cope with the demands of the Accelerated Mahaweli Programme.

Watershed Management

In 1980, it was estimated that severe erosion was taking place in a large part of the 316,000 ha. of the upper catchment areas of the Mahaweli, due to factors such as the felling of forest by area residents and similar misuse of land. Only 14% of the upper catchment area was estimated to be under forest in 1980, and another 49% was estimated to be under well-managed agriculture, mainly in the form of tea plantations.

Although soil erosion was unlikely to seriously affect the projected life span of 50 years of the major reservoirs constructed under the Accelerated Mahaweli Programme, in order to reduce soil erosion and to make us of these lands for agricultural purposes - including the supply of fuelwood and timber - it was proposed that a substantial reforestation programme should be launched.

The action plan for 1981 noted that there were several on-going reforestation projects for the upper catchment areas sponsored by governmental and non-governmental agencies, including foreign agencies. In order to coordinate these activities the Ministry of Lands and Land Development brought the reforestation programme for the upper catchment area under its purview as of 1981. It was estimated in 1981 that the existing reforestation programmes (mainly fuelwood) covered about 36,000 ha. of land in the upper catchment areas. In 1983, MASL inaugurated a programme to reforest the upper catchment areas of the Victoria and Kotmale reservoirs. In addition, the Forest Department is also implementing a programme to reforest the balance Mahaweli upper catchment areas.

Wildlife Habitats and the Preservation of Wildlife

It was assessed in 1980 that the clearing of a major part of the forests in the Accelerated Programme areas for settlement and cultivation would reduce substantially the wildlife habitats

available in the dry zone. Unfortunately several species of wildlife internationally acknowledged to be endangered or threatened, including elephants and other species endemic to Sri Lanka, inhabit these areas.

In order to mitigate the adverse impact on wildlife, the government has committed itself to preserve the Wasgomuwa Strict Natural Reserve, the Somawathiya Sanctuary, the flood-plain reserve (villu areas on both banks of the Mahaweli Ganga between the Wasgomuwa and Somawathiya reserves not earmarked for development) and riverine forests along the rivers and streams of all major project areas for a distance of at least 200 meters from either bank. The government has also committed itself to create the Madura Oya National Park as a wildlife habitat. The Wasgomuwa and Somawathiya reserves, and the Madura Oya and floodplain National Parks at full development will constitute 198 000 ha. or 47% of the gross areas earmarked to be developed under the Accelerated Programme.

In accordance with the proposals contained in the action plan of 1981, a management programme for wildlife has been put into effect in 1983. The staff trained under this programme will manage the wildlife reserves and will also help to prevent the encroachment of wildlife into cultivated areas.

Other Environmental Programmes

The other environmental programmes for the Mahaweli areas relate to monitoring the quality of surface and ground water, the development of fisheries in the reservoirs of the various systems and village tanks, and the launching of a programme of environmental awareness in the Mahaweli areas.

The water quality monitoring programme is now in operation in Systems B and H and is being carried out by the National Resources, Energy and Science Authority. The Ministry of Fisheries is in entire charge of the fisheries development programme,and the programme for the Mahaweli areas has been launched under the auspices of the Inland Fisheries Development Programme. The progress made up to now consists of theestablishment of fisheries stations for breeding and distributing fingerlings in System B. In 1982, activities on environmental awareness were coordinated by the Victoria Project Office. The programme comprised training of downstream area unit managers in environmental awareness, addresses delivered on the subject to school children and teachers and to youth in Systems B, C, H and G, broadcasts by radio, and publication of feature articles in newpapers.

REFERENCES

R.H. Brooks

United States Public Health Service and Tennessee Valley Authority, 1947. *Malaria Control on Impounded Water*, US Government Printing Office, Washington.

Additional References

Ackers, G.L., and Smith, D.H., 1988. Design and management of development projects to avoid health hazards, *J. Trop. Med Hyg. 91*: 115-129

Avery, R.S., 1954. *Experiment in management: personnel decentralization in the Tennessee Valley Authority*, Knoxville, Tennessee, University of Tennessee Press, 212 p.

Bottrall, A.F., 1981. Comparative study of the management and organization of irrigation projects, *World Bank Staff Working Paper no. 458*, Washington D.C.

David, L.J., 1988. Environmentally sound management of the Zambesi River basin, *Water Resources Development 4 (2)*: 80-102

Goonasekere, K.G.A. and Amerasinghe, F.P., 1989. Planning, design, and operation of rice irrigation schemes - their impact on vector-borne diseases, in: *Vector-borne disease Control in Humans through rice agroecosystem management*, International Rice Research Institute, Manila.

International Irrigation Management Institute and the joint WHO/FAO/UNEP Panel of Experts on Environmental Management for Vector Control, 1986. *Proceedings of the Workshop on Irrigation and Vector-borne Disease Transmission*, IIMI Publ. 86-02, Digana Village, Sri Lanka.

Tennessee Valley Authority, 1983. *A History of the Tennessee Valley Authority*, Sybil Thurman (ed.), TVA Information Office, 48p.

Tennessee Valley Authority, annually. Vector Control Activities Tennessee Valley, *TVA Technical Report Series*, Division of Air and Water Resources, TVA, Knoxville.

Tiffen, M., 1987. The dominance of the internal rate of return as a planning criterion and the treatment of O & M costs in feasibility studies, *ODI/IIMI Irrigation Network Paper 87/1b*, Overseas Development Institute, London.

Wijesundera, M. de S., 1988. Malaria outbreaks in new foci in Sri Lanka, *Parasitology Today 4(5)*: 147-149.

World Commission on Environment and Development (WCED), 1987. *Our Common Future*, Oxford University Press, 400p.

World Health Organization, 1986. *Intersectoral Action for Health, the role of intersectoral collaboration in national strategies for health for all*, Geneva, 124p.

WHO FAO UNEP

PEEM 1985

THE ENVIRONMENTAL IMPACT OF POPULATION RESETTLEMENT AND ITS EFFECT ON VECTOR-BORNE DISEASES

Population migration and resettlement are intrinsically linked to economic development. In search for new opportunities to improve their quality of life, people move from less developed to industrialized countries, from the rural areas to big cities, and from city slums to areas where resource development is taking place. New migration patterns may arise when agricultural development results in the introduction of crops requiring seasonal labour, such as the harvesting of cotton. And finally, economic development may lead to the forced displacement of people, to create space for industrial parks, infrastructure and man-made lakes.

Invariably a component of resource development projects, and of all components the one where the triangle environment-vector-pathogen comes to its clearest expression in the human health situation, authorities in most countries have nevertheless great difficulty to cope with the adverse health effects of these demographic changes. The major malaria foci of today are found in areas affected by civil strife or undergoing major natural resource development. The paper by Roundy describes, in general terms, the many facets of resettlement, and lists a number of issues that should be checked at the planning stage of any projects, to mitigate possible adverse health effects.

The role of population migration in the spread of diseases is illustrated in the second paper, which describes the role of seasonal workers in the spread of schistosomiasis in Ethiopia. Many other examples could be given, including the role of workers from Anatolia in the malaria epidemic around Adana in Turkey in the 1970s (Gratz, 1987), the role of migration in the spread of chloroquine resistant malaria in Thailand, the introduction of Chagas disease in some urban areas in Brazil (Marsden, 1984, Zeledon, 1981), and the introduction of schistosomiasis in the Mwea Rice Irrigation Scheme in Kenya (Waiyaki, 1987).

Previous technical discussions focused on the engineering aspects of water resource development, and the Panel recommended the incorporation of health safeguards in planning and design of structural, project components. The major conclusion of this technical discussion was that early involvement of the health sector in planning should lead to timely strengthening of health services, so as to adequately meet the increased needs for the monitoring of resident and resettled populations. In case of external donor support, additional funds for the strengthening of health services should be negotiated. There is an obvious need for institutional arrangements to govern the collaboration with the health sector, and this is emphasized in the paper by Meskal.

RESETTLEMENT: A SYSTEMATIC OVERVIEW OF A DIVERSE PHENOMENON AND ITS IMPACT ON THE ENVIRONMENT AND VECTOR-BORNE DISEASE TRANSMISSION

by

Robert W. Roundy

INTRODUCTION TO RESETTLEMENT AND HEALTH RISKS

Resettlement, whether planned or unplanned, occurs throughout the world. Resettlement in the less developed countries of the Third World (Africa, Latin America, and much of Asia and Oceania) may be associated with a change in human disease prevalence and incidence as populations in the hundreds, tens of thousands (major dam-associated resettlements at the Volta Dam in Ghana, the Kariba Dam on the Zambezi, the Ubolratana Dam in Thailand, or the Kainji Dam in Nigeria), to hundreds of thousands (the resettlement of Nubians with the creation of Lake Nasser behind theAswan High Dam), to a million or more (transmigrants in Indonesia from Java to the outer islands, residents and migrants on the Gezira Scheme in Sudan, planned but nowhere near achieved resettlement in conjunction with the Transamazonian Highway in Brazil) are resettled in new, often different habitats.

Depending on the project in question, health may or may not be considered as a major constraint to the success of resettlement. Health problems may, in fact, be completely ignoredwhen constraints are listed. In some Amazon and African studies, for example, emphasis is given to what are deemed the more significant problems of administration, provision of infrastructure, and access of settlers to support agencies (Chambers, 1970; Schuurman, 1980; Smith, 1981). Where health is included among major constraints it is one of many (Moran, 1985; Ortiz, 1980; Stearman, 1983),and usually not considered as significant as other problems such as defects in agricultural planning and credit provision (Moran, 1981; Smith 1982). Rarely, and nowadays only in historical reports, is disease described as the predominant constraint on resettlement and development, as evidenced by reports of the role of malaria, yellow fever, and other tropical diseases in Latin American settlement during the Spanish conquest (Bromley, 1980); malaria in the disabling of settlers inexpatriate colonization schemes in Paraguay in the first third of this century (Stewart, 1967); and malaria as a roadblock to Ceylonese Dry Zone development in the 1930s and 1940s (Farmer, 1957).

Where the importance of health problems is recognized, they may or may not include vector-borne diseases. Wherever a single disease is named as a major constraint to resettlement it is most often malaria (Korte, 1973; Moran, 1981; Scudder, 1981; Smith, 1982) and whenever many disease problems are named they may include vector-borne diseases as a group (Weil, 1981). But most often, in resettlement literature, vector-borne disease risks are ignored or are only one of many risks to health noted.

Dr Roundy is Assistant Professor at the Department of Human Ecology and Geography, Cook College, Rutgers University, New Brunswick, New Jersey, USA

A comprehensive list of disease constraints to resettlement success was composed by the author based on hospital reports, collections of settlers' complaints, and a literature review (Colson, 1971; Crosby, 1985; Farmer, 1957; Imevbore, 1975; Johnson, 1982; Korte, 1973; Macdonald, 1955; Meade, 1974; Moran, 1981; Scudder, 1981; Smith, 1981, 1982; Townsend, 1985; Waddy, 1975; Weil, 1981). It should ideally include:

- diseases from poor hygiene, such as diarrhoea and dysentery, intestinal parasites, gastroenteritis and skin diseases;
- diseases associated with crowds and crowding, such as respiratory diseases and veneral diseases;
- nutritional diseases;
- toxic disorders;
- psychological distress associated with relocation;
- trauma from snakebite scorpionsting, leeches and the like;
- trauma from accidents associated with labour activities, or associated with growing affluence, as motorcycle and vehicular accidents;
- a variety of other disorders, such as conjunctivitis, anemia, goiter, childhood diseases, problems of the reproductive system, and dental decay.

The resulting viewpoint, when health is a primary concern, may be that health risks at resettlement sites may include, but are not solely associated with vector-borne diseases. Rather, there may be a strong emphasis on:

- the diseases of poverty, which may include vector-borne diseases, but also other communicable diseases and diseases of malnutrition;
- at the initial stages of resettlement new, previously unknown threats to health, as toxins from unknown plants and attacks by wild animals such as snakes, problems that probably affect few people, but affect them in a spectacular, possibly fatal way;
- health problems associated with the traumas of change, as accidents in land clearing and farming that may result in lengthy disability and accidents associated with growing affluence, as seen on Felda Schemes in Malaysia.

VARIABLES IN RESETTLEMENT

Initially, organized resettlement takes one of two basic forms. It may be aimedto open up and utilize a natural resource to attain some public good. Contrarily, resettlement occurs when an established population is displaced as part of the attainment of a public good, such as water

resource development (in particular, the creation of reservoirs for hydropower and/or irrigation), or for the creation of agricultural estates, for urban or industrial development, or for preservation.

When people are resettled to attain a public good various driving forces to resettlement may exist individually or simultaneously. These include:

- agricultural colonization to use land or water resources productively, as evidenced by Felda Schemes in Malaysia (Bahrin, *et al.*, 1983) and the Mwea Scheme in Kenya (Chambers, 1969).

- the opening of access to mineral and forestry resources, as in the Amazon basin (Scudder, 1981).

- satisfying of political needs, such as (a) opening development frontiers and establishing a national presence, as in the Amazon (Scudder, 1981; Smith, 1981), transmigration in Indonesia (McAndrews *et al.*, 1982) and smaller programmes in the Philippines (Andersson, 1982); (b) avoiding of political or economic disruptions as likely to result from land reform in already settled areas (Dickenson *et al.*, 1983), and, (c) reducing dissatisfaction among a segment of a population, through the provision of jobs or lands, as seen in Malaysian Felda Schemes (Bahrin, *et al.*, 1983).

- relieving demographic pressures elsewhere, as in the North-East of Brazil (Smith, 1981), the non-Brazilian Andes (Stearman, 1983), and on Java (McAndrews *et al.*, 1982).

- associations with human health aspects, such as (a) taking advantage of advances in health sciences that allow control of formerly restrictive diseases, making possible the colonization of formerly malarious areas such as the Terai in India (Farmer, 1974), the llanos of Venezuela (Crist and Nissley, 1973), and Mwea in Kenya (Moris, 1973) and of a cattle trypanosomiasis-affected area in Mwea (Chambers, 1969) or (b) in the early 20th century, evacuating people from sleeping sickness-areas in Africa to safe resettlement areas (Chambers, 1969).

Populations resettled to attain a public good are most likely to be considered for resettlement support because successful resettlement often is an implicit part of the public good sought.

People whose resettlement is a consequence of displacement from a development area are less likely to receive much support in their move. They are often considered a barrier to development rather than a resource to develop. Furthermore, populations that are considered for displacement may be less powerful to begin with, making them less able to guarantee equitable resettlement. In the worst cases, displaced resettled communities may not receive adequate compensation for lost land and resources, may be settled in an environment very different from the place of origin, requiring major adaptations of the settlers, may be settled on marginal land or may be isolated from other populations, lacking local amenities and with poor access to amenities elsewhere (Anderson, 1982; Goldsmith and Hillyard, 1984; Harinasuta *et al.*, 1975; Johnson 1982; Scudder, 1975).

Consequently, populations undergoing resettlement of either one of these two types may face different risks and have access to different kinds of support.

Beyond this elementary dicotomy of resettlement types there are other variables between schemes that may influence human health, especially as they relate to exposure to disease transmission, the creation of habitats favourable to disease vectors, intermediate hosts and reservoirs, and the spread of diseases. These variables may also influence the availability of resources to deal with disease and an immediate impact on the financial and other resources available to support adequate health services include:

- the size of the population undergoing resettlement;
- the homogeneity or heterogeneity of the population (place of origin, ethnicity, language, religion, etc.);
- the density of the resettled population and the amount of productive land available to individual settler families;
- the question of whether all settlers are centrally selected, or if resettlement area populations may also include unselected squatters and passers through;
- the variety of environments from where settlers may come and where they may go to, including variables in climate, soils, water resources, flora and fauna;
- the previous experience of resettlers with their new types of habitats and occupations;
- the mobility of inhabitants once resettled, and the arrival of periodic visitors to the schemes;
- whether or not the resettlement includes domestic animals;
- the duration of the resettlement process, from being a single event to an affair drawn out over decades;
- whether the resettlement programme includes support components, such as land clearance and development, housing and settlements, finance and credit, market access, public services including water and sanitation, education, and health care. In this respect, Felda Schemes are described as fully serviced (Bahrin *et al.*, 1983), Kainji resettlements and services as expending 12.6% of the total project budget (Imevbore, 1975), and Mwea as receiving little beyond agricultural services (Korte, 1973). In case support components are included, a second question is whether there is a difference in access to such services for the various settler groups. In Gezira unequal access to services for settlers and labourers (Amin, 1984; Fenwick *et al.*, 1982) and in the Amazon region uneven distribution of services is mentioned, with some services poorly equipped, understaffed, requiring long waits, and being periodically inaccessible (Moran, 1985; Smith, 1982; Townsend, 1985).

Once resettled, populations may face risks from vector-borne diseases. To illustrate risks, and how humans influence them, we should think in terms of interactive disease systems. These

systems require specific organisms, the agent, an obligatory vector, susceptible human hosts, and possibly also other hosts appropriate to the agent, and habitats appropriate to the survival, reproduction, andinteraction of these organisms.

In the framework of such interactive disease systems, resettlers can play four specific roles in the transmission patterns of vector-borne diseases (Roundy, 1978). In addition, behavioural aspects may knowingly or unknowingly be related to human health and may also have either positive or negative consequences for human health. The four principal roles are exposure, shedding, the creation of man-made habitats, and diffusion.

EXAMPLES OF ALTERED ENVIRONMENTS IN RESETTLEMENT AND VECTOR-BORNE DISEASE RISK

With this background of (1) the phenomenon of resettlement, predominanttly occurring Third World countries, with its variable manifestations; (2) the recognition that disease, including vector-borne disease, may or may not be considered a major constraint to the success of resettlement; and (4) the description of how resettled populations may influence the epidemiology of the diseases they face, we can turn to examples of alterations in environments in resettlement endeavours and resultant changes in vector-borne disease transmission. These changes are most frequently adverse to human health, but they may at times be positive, leading to reduced levels of vector-borne disease transmission.

Exposure

Resettled populations may be exposed to vector-borne disease transmission in a general way by entering new habitats or by selective exposure within the resettlementarea. The first to be exposed are those in charge of preparing areas for resettlement, including land clearing and dam building crews. In Thailand, dam construction teams have been exposed to malaria; at the Kainji Dam in Nigeria construction teams were housed 10 miles from the river to avoid onchocerciasis. Some outbreaks of yellow fever are reported from the Amazon region among people who clear land, although clearance is not a necessary condition for resettlements (Causey and Causey, 1974). It has been observed that settlers in the Amazon region usually clear land in the dry season which coincides with a decline in sylvatic vectors, which in turn reduces exposure to yellow fever (Moran, 1981; Smith, 1982)

When populations move into an area for permanent resettlement, they may invade an existing disease focus. In Kariba Dam resettlement in Rhodesia (now Zimbabwe) people moved from the river valley into upland bush with a resulting increase in trypanosomiasis. Some people resettled from the reservoir area behind the Ubolratana Dam in North East Thailand ended up in villages in malarial foothills (Harinasuta *et al.*, 1975). In the Felda Resettlement Schemes in Peninsular Malaysia Melinda Meade (1974) reported that "Settlers going to new schemes can almost expect to contract malaria".

For some major resettlement projects in Africa fears of exposure to new vector-borne diseases was expressed, although these fears did not necessarily come to immediate fruition. The resettlement of Nubians from Wadi Halfa to Khasm el Girba in Sudan on the completion of the Aswan High Dam was recognized as a movement from a desert to a seasonally wet semi-arid area with attendant risks of new exposures to malaria, kala azar, onchocerciasis, and other ar-

thropod-borne diseases (Brown and Deom,1975; Sandder, 1975). People resettled from the Kossou Dam in Côte d'Ivoire were said to be exposed to sleeping sickness (Brown and Deom, 1975).

Once in the resettled area there can be differential exposures to vector-borne diseases. Melinda Meade's dissertation study of Gedangsa, a Felda scheme, (1978) showed inappropriate house siting, plantation-crop economic activities, limited hunting, fishing and collecting of fuelwood as possible risk factors, while on the other hand the availability of water fromstandpipes kept people away from forest vectors. Simultaneously, undrained swamps and scrub vegetation in the resettlement village left people potentially exposed to malaria and scrub typhus. But overall, the preponderance of behaviour avoided exposure to biting vectors.

In the Amazon region certain types of behaviour can be associated with increasing or declining exposure to malaria near the settlement. Malaria is a year-round risk, but peaks with the major agricultural activities, such as times for planting, harvesting, and land clearing (Moran, 1981; Smith, 1981), thus influencing exposure levels of farmers. In selected areas it was also found that males who bathed in ponds after a day's work were more exposed to malaria vectors than were females, who bathed at similar sites earlier in the day (Johnson, 1982). And males in a new settlement area who lived on farm lots were exposed to malaria while their families who stayed in town were not. When the families eventually moved to the farms women and children too came down with malaria (Moran, 1981).

Settlers who journey beyond village boundaries may be exposed to different vector species, or higher vector densities. Such behaviour may be encouraged in the early stages of resettlement, when foraging for fuel, timber, or plants or hunting and fishing may supplement meager incomes. Exposure to malaria is seen with such behaviour in Thailand (Harinasuta, *et al.*, 1975) and risk from leishmaniasis is cited from the Amazon region (Moran, 1981).

Shedding

For diseases transmitted by biting insect vectors, types of behaviour leading to exposure are congruent with those leading to further transmission. For schistosomiasis, however, shedding is a separate behaviour.

Shedding, or excretory, behaviour in resettlement programmes in Sudan can be seen to influence schistosomiasis prevalence. Frequent human excretion into or near irrigation channels leads to the infection of intermediate host snails. Especially migrant workers, who often lack access to clean water and sanitary facilities may also shed pathogens (Amin, 1984). Precisely when and where migrant labourers shed parasite eggs has been shown by Fenwick and his coworkers (1982) to vary by social/cultural group so the appropriate public health response to prevent water contamination can not be universal for all cases. The consequences of shedding dominated by a subgroup of the population, i.e., the migrant labourer population who lacks access to hygienic services, is however an active focus of schistosomiasis transmission for all inhabitants of the resettlement area.

Manmade habitats

Manmade habitats can be significant when they bring together and allow the interaction of pathogens, vectors, susceptible humans, and other intermediate or reservoir hosts. The role of

man-made habitats in vector-borne disease transmission in resettlement areas can be illustrated at various scales.

At the regional scale, water resource development may influence environments and vector-borne disease risks. The result may sometimes be a reduction in disease, as on the Volta reservoir where river-fringe forests in northern Ghana were drowned, destroying *Glossina* breeding sites (Kuzoe, 1975), on the Kainji reservoir, where *Simulium* breeding sites were drowned (Imevbore, 1975), and in the Awash Valley of Ethiopia, where there was a decline of *Schistosoma haematobium* transmission apparently from the destruction of small swamps and reduction of large ones (Kloos, 1985).

But water resource development may also enhance risk as with the increase of *S. mansoni* in the same Awash Valley (*Ibid.*). Irrigation development led to the introduction of schistosomiasis to the Gezira area (Amin, 1984) and a seventy-fold increase in *Anopheles gambiae* population on the Kano Plain in Kenya (Brown and Deom, 1975) In Trengganu State in North East Peninsular Malaysia a dam-reservoir-irrigation system enhanced *Anopheles maculatus* breeding and malaria, as well as vector populations capable of transmitting *Brugia malayi.*

Regional vegetation change may also enhance vector-borne diseases. Malaria in the Transamazon Highway area can be associated with highway construction and forest clearance (Moran, 1981).

On a local scale, a variety of man-made habitats can be associated with vector-borne disease risk, including:

- clearing land for farms can increase vector numbers, as with the increased breeding of *Anopheles minimus* and consequent increase in malaria at the Srinagarind Dam resettlement in western Thailand (Harinasuta *et al.*, 1975) and the expressed concern that land clearance on Felda Schemes may enhance *A. maculatus* breeding (Meade, 1974)

- creating irrigation schemes can yield increased malaria and schistosomiasis vectors, as at the Rice Irrigation Scheme in Kenya Mwea where drains and ditches are not well maintained and cleaned (Korte, 1973)

- road building, as in the Amazon region, may result in borrow pits that become breeding sites for malaria vectors and mosquitoes capable of transmitting Bancroftian filariasis if this disease should be introduced to the area (Moran, 1981; Smith, 1982)

- the settlement itself may be tied to man-made foci of disease. In one of the Felda Scheme resettlement the village lay-out is agglomerated, not linear, so houses are in a non-forest area and away from some malaria vector species, but the settlement is also near natural undrained swamps, with resulting malaria risks, and also inundated with a lalang (*Imperata cylindrica*) grassland on human cleared, but undeveloped land, which can become a focus of scrub typhus transmission (Meade, 1974; Meade, 1978).

At the micro-scale the man-made habitat around individuals may be changed and influence vector-borne disease transmission. Some examples include:

- storage of domestic water in open containers in homes, where *Aedes aegypti* vectors of yellow fever, and dengue/dengue haemorrhagic fever may breed (Brown and Deom, 1975)

- houses at the Mwea Rice Irrigation Scheme being conducive to malaria transmission, both because mosquitoes are encouraged by dark, poorly ventilated structures (Korte, 1973) and because open fires in houses yield soot-covered walls so anti-malarial spraying is less effective (Korte, 1973)

- keeping of dogs and other domestic animals in the Amazon region which can serve as reservoir hosts of Chagas' disease if the right vectors are introduced into the region. Further more, local housing structures and building materials are appropriate for infestation by tri atomine vectors of the disease (Smith, 1982).

Diffusion

Settlers may carry vector-borne diseases from one place to another. Schistosomiasis, for example, was introduced to the Gezira, *Schistosoma haematobium* agents perhaps brought in by Egyptians, *S. mansoni* by White Nile farmers (Amin, 1984). Malaria, too, was increased in the Gezira as it was brought in by workers from malarious areas (Brown and Deom, 1975).

Currently in the Sudan it is believed migrant workers carry schistosomiasis fromone redevelopment area to another. An example is the Rahad Irrigation Scheme on a tributary to the Blue Nile, where settled locals were not infected prior to the scheme, but immigrants and migrant labourers are infected with *S. mansoni* (Amin, 1984).

There are concerns in other areas that the mobility of people will diffuse vector-borne diseases to new sites. There has been great concern expressed in the Amazon that highways and setlements will create new disease foci, introducing more effective vectors of Chagas' disease, pathogens and vectors of Bancroftian filariasisand schistosomiasis, pathogens of onchocerciasis, and more accessible susceptible human hosts to existing zoonoses of yellow fever and leishmaniasis (Moran, 1981).

ENVIRONMENTAL CHANGE, VECTOR-BORNE DISEASE RISK, AND HEALTH RELATED RESPONSE

In order to minimize vector-borne disease risks in resettlement programmes a number of actions could be considered, which may vary from programme to programme, depending upon the actual risks faced, the population facing them, and the resources available to combat the risks.

A first obligation for those concerned with human health in resettlement is to assess the importance of vector-borne diseases in the context of a resettlement programme, both in absolute sense as a constraint on overall development and in relative sense as one of a number of human health constraints on the programme. This assessment serves to identify the level of resources needed specifically for vector-borne disease control.

Given the variety of factors contributing to the success or failure of a resettlement programme and the limited resources available to deal with the various constraints that may present

themselves, investment in vector-borne disease control is likely to be most adequate in those cases where preventive or corrective measures have multiple benefits, not just the control of a single disease or set of diseases. For example, environmental management measures in water resource development to control malaria or schistosomiasis can more readily be justified when they are shown not only to reduce disease prevalence and incidence, but also to have such effects as increased productivity, a reduction in other diseases such as those of poor hygiene, a reduction of female labour time so that women can dedicate themselves to other productive domestic or commercial purposes, and improvement of morale and community spirit in the resettled population. Likewise, health education programs, usually necessary if new or changed habitats are to be continuously productive, can be integrated into other existing education or extension programmes rather than being set up independently, probably at a higher cost.

The availability of resources for delivery of adequate health services may be highly variable in resettlement programmes. A lot depends again on whether resettlement is the desired development end or resettlement is the method used to remove people from the site of desired development. This may directly influence the resources available and the effort made to control disease constraints on resettlement. Populations moved to make way for development may also be less able to generate their own resources for health care. In the process of being removed from homelands community structures may disintegrate and communities may become alienated from their governments and the programmes meant to serve them.

Other variables between schemes may also influence hazards faced and mechanisms available to mitigate them. A number of these variables are listed below together with some pertinent questions that may be asked at the planning stage of a resettlement programme.

Size of the resettled community

☞ does it overwhelm existing or planned health services?

☞ does it reach a threshold to justify the creation of local services?

☞ What is the nature of the relationship between the size of a resettled community and the impact on the environment?

Homogeneity/heterogeneity of the resettled community

☞ how readily can the population become a functioning community?

☞ can the numbers of the resettled community work together, or are they divided in their priorities of needs?

☞ does heterogeneity broaden the range of environmental impacts, ensuing health risks, and locally suitable responses to them?

Density of the resettled community

☞ is the population sited so central services are accessible, or is it dispersed?

- ☞ does density itself associate with increased or decreased risks? (e.g. high density could create habitats that discourage leishmaniasis but encourage dengue)?

- ☞ is density so high that there is insufficient land per family, thus excluding possibilities for equitable and sustainable development towards increased human welfare?

Selected vs. unselected settlers

- ☞ will selection of settlers result in a better representation of a full range of needed abilities and experiences in the communities?

- ☞ might spontaneous settlers overwhelm services or not be served at all, thereby generating health risks for the total community?

- ☞ could spontaneous settlers exert uncontrolled influence upon the water, land, vegetation, and animal resources necessary to productivity and health?

- ☞ might, as has been suggested (Saunders, 1974), selected settlers show greater dependency on authorities and be more willing to abandon a resettlement programme, while spontane ous settlers appear more committed, more aggressive, and more able to take initiative, for example in the implementation of environmental measures to control diseases?

Resettled habitat

- ☞ can a study of habitats help determine if vector-borne disease risks will be introduced to or altered at resettlement sites?

- ☞ recognizing that many of the diseases of interest are not ubiquitous, can knowledge of resettlement habitat types help predict how (which way, to what degree) risks change?

Settler experience with new habitats/occupations

- ☞ how quickly can settlers adjust themselves (physiologically, immunologically) to the resettlement habitat?

- ☞ will their previous habits be appropriate to new habitats or will they generate risks?

- ☞ how quickly can new skills be learned to make settlers productive and better able to support risk-mitigating services?

Population mobility in resettled areas

- ☞ will likely population movements diffuse diseases in and out of the resettlement area?

- ☞ will mobility lead to regular exposures to disease beyond the confines of resettlement villages and production areas?

- ☞ Migration patterns imply that services (health care, environmental management, health education) must be afforded equally to both formal and informal (spontaneous or migrant labourers) settlers on the scheme to be effective

Animals in resettlement

☞ can animals serve as disease reservoirs?

☞ will the animals afford benefits through zooprophylaxis?

☞ are the animals necessary to the economic or dietary success of the scheme, thereby con tributing in their own way to good health and reduced risks?

Duration of resettlement efforts

☞ need all services, including health-related services, be on-line at the commencement of a scheme, or can they be added or enlarged upon gradually as demands and circumstances evolve?

☞ will the resettlement effort last long enough that programmes and risks can be monitored and adjustments made to fit local conditions?

☞ will services be subsidized throughout, or is it assumed resettled populations shall eventually generate their own support funds?

Support systems

☞ will the resettlement scheme be able to provide all desired supports everywhere,all the time, and to everyone, or will available finances and staff limit supports to selected constraints and/or areas?

☞ how will the resettlement programme keep its staff in place and supplied? (even in showcase areas in the Amazon region difficulties have arisen keeping staff on the job (Moran, 1983) and when services break down settlers may abandon the resettlement (Moran, 1985).

☞ how will services be prioritized, and will the emphasis be on those that encourage productivity, maintain governmental controls, or provide for settler well-being?

Disease-related human behaviour helps to indicate how and where scarce health resources can best be utilized. Exposure-related behaviour suggests that land clearers and construction teams at resettlement sites should be well protected from local vector-borne diseases. They are themselves at risk, but just as importantly can readily serve as highly mobile diffusers of the diseases as they move from resettlement to resettlement. Once the resettled population is in the area risk-related sites and types of behaviour should be monitored. As habitats are altered with development, vector-borne diseases can be influenced for better or for worse. Exposure risks identified may well be temporary risks and mitigated by changing the time and place of hazardous behaviour, a change not always possible if a necessary production activity yields the exposure. Where exposure sites are visited for hunting, fishing, or foraging incentives such as compensation and organized food supply systems may disrupt exposure.

Shedding in vector-borne diseases relates specifically to excretory behaviour and its influence on schistosomiasis. Proper sanitation is imperative in resettlements that include water

resource development. As seen in the Gezira, sanitation is needed not only for permanent, formal settlers, but perhaps even more important, for occasional visitors to the scheme and for migratory labourers. Lack of provision of public services that promote proper hygiene yields unsafe and uncontrollable shedding risks for the disease.

The understanding of the influence of man-made habitats on vector-borne disease hazards in resettlement environments is absolutely necessary. Resettlement areas are necessarily re-worked by humans. Impacts on the environment can be generalized, but each specific community should be monitored to see how local habitat changes are influencing disease risk. Habitat changes can increase or decrease disease risk, or even simultaneously encourage one disease while discouraging another. And this influence on disease can vary by habitat scale, so that community-behavioural impacts can be at odds with the impact of the behaviour of a few individuals within the community.

Diffusion of vector-borne diseases to and within resettlement areas warrants active monitoring. Sustained good health may require stringent mobility controls and quarantines, which may not be feasible if they are too disagreeable to settlers and compete with the production demands for periodic labourers.

The various health-related responses explicitly and implicitly sollicited here suggest that they can best be satisfied if their needs are recognized from the beginning of resettlement efforts. Given the variable significance of vector-borne diseases to resettlement and the limited resources to mitigate such diseases, the best response is a preventative one, not a curative one. Therefore, representatives from the health sector should be involved in resettlement efforts from the beginning of the planning stage. This will ensure that planned actions can be judged for their impact on the environment, and those actions which encourage exposure, ignore shedding, misjudge the consequences of man-made habitats, or encourage disease systemdiffusion can be redesigned or accompanied by on-the-spot disease-mitigating measuresand services. To succeed in this endeavour resources are needed. These resources include funds, but perhaps just as importantly public health personnel with sufficient time for analysis and experimentation, access to the resettled population,and constructive collaboration with other agencies associated with the resettlement effort.

In risk abatement, resettlement organizations cannot think of vector-borne disease risks as being homogeneous. Risks will vary absolutely and relatively from place to place, and in time. Appropriate approaches to mitigate these risks shall also vary from place to place, and should be based on not just a few environmentally-oriented strategies, but include a broad combination of attacks on the variety of hazards present, simultaneously influencing the disease agents present, their various vectors and hosts, and the changeable aspects of human behaviour of importance to risk in the resettlement area (Imevbore, 1975). Risk abatement analysis and implementation, like resettlement plans in general (Moran, 1985, Smith, 1982), cannot be instigated in some office far from the scene. The results of organization from a distance will be general models (much like this paper), not usable plans, with emphasis on quantifiable results instead of human well-being, and concern for the details of the plan instead of the actual implementation of improvements.

Properly planned and implemented, or as the result of blind luck, health conditions in resettlement areas can be genuinely better than the conditions prevailing in traditional, non-resettle-

ment communities. Meade found for Felda schemes that while it might take some time, on mature schemes almost every health complaint category had decreased in incidence (1975). Indeed, she concludes that major health concerns in resettlement eventually are not those of deteriorating conditions, but of the failure to achieve all the potentials for improved health that resettlement appears to offer. This argument is supported by the experience in Thailand, where resettlement programmes that yielded greatly improved economic conditions did not yield a comparable improvement in the health of communities, with greatest problems associated with poor hygiene, poor diets, and inadequate use of a wide range of health services (Harinasuta *et al.*, 1975).

VECTOR-BORNE DISEASES RELATED TO LABOUR MOVEMENT AND ARRANGEMENTS FOR THEIR CONTROL

by

Fisseha Haile Meskal

INTRODUCTION

In the absence of too much human activity in and around aquatic environments, the tendency is for major vector-borne diseases like malaria and schistosomiasis to be restricted to limited foci. Alarming outbreaks of such diseases usually accompanywater resource development schemes, which encourage concentration of human communities close to waterbodies and extensive movement of people to and from such places. It is now well known that "water resource development projects ... create new aquatic habitats which are favourable for the production of a variety of invertebrates that transmit diseases to man" (McMullen *et al.*, 1962). Several authorities including Schaller and Kuls (1972) have also indicated that migration ofpeople from areas where vector-borne diseases are prevalent to newly developed irrigation projects could favour the introduction and spread of such diseases.

This fact was not fully appreciated until recent years, and, as a result, many water resource development schemes in Africa have failed to meet their objectives because of the ensuing heavy toll of mortality and morbidity. Disease outbreaks following the construction of such dams as the Volta, Kariba and Kainji, and the Gezira irrigation system are often cited as typical examples of health problems associated with water resource development. Of the total human population exposed toschistosomiasis, for example, Wright (1972) estimated over 2.5 million to be totally incapacitated, and close to 28 million to be partially disabled. The total loss of productivity due to partial and total disabilities is believed to be well over US$ 900 million. It does not, however, include the unmeasurable loss due to the accompanying mental retardation and intellectual dullness caused by the parasite.

Conventional control methods for well-established and widely spread vector-borne diseases in water resource development schemes are proving too costly for individual projects. Thus, Bradley and Webbe (1975) pointed out that the 1975 estimate for chemical control for the Gezira irrigation system (1 million acres) was approximately US $1.6 million. The molluscicidal application in the periodic irrigation schemes of Iraq was estimated to cost US $0.70 to 2.00 per acre, and there were then about 8 million acres under various types of irrigation. In Egypt, the annual cost of molluscicide and its effective application in the 5.5 million acres of permanent irrigation was estimated at US $1.35 to 2.25 per irrigated acre. The only alternative to this recurring expenditure is to find efficient organizational arrangements to mitigate the spread of vector-borne diseases with development of irrigation and other water-related projects.

Obeng (1977) recommends the use of available information in planning future water develop-

Dr Fisseha Haile Meskal is General manager of the National Research Institute of Health, Addis Ababa, Ethiopia

Figure 1. Location of the Awash Valley in Ethiopia and its irrigation schemes.

Source: H. Kloos, 1985

ment schemes so as to minimize the inevitable health problems. Some water agencies like the Water Resources Development Authority of Ethiopia and the Kenyan Interministerial Committee on Environmental Impact Assessment of Industries (Bos, 1984) appear to have arrangements by which health problems associated with water resource development can (or in the Kenyan case, could) be minimized. Other countries and even individual development projects are perhaps experimenting with different organizational arrangements to prevent health hazards associated with such development. Although there does not appear to be any single fool-proof disease control method that is universally applicable to all conditions and situations there is a possibility of developing one or more efficient organizational arrangements to minimize the spread of vector-borne diseases resulting from water resource development schemes. That is why the WHO/FAO/UNEP Panel of Experts on Environmental Management for Vector Control

has recently expressed interest in the development of "adequate institutional arrangements to ensure the incorporation of health and environmental safeguards in water resource development projects" (*PEEM Newsletter No. 11*, March 1985). The objective of the present communication is to examine prevailing circumstances with regard to vector-borne disease transmission in development areas of Ethiopia, in particular the migration patterns involved, and to present for discussion existing and recommended organizational arrangements for the prevention and control of the diseases.

In this paper we will first present a bird's-eye view of the major water resource development region of Ethiopia, the main vector-borne diseases in that region, and how these diseases are disseminated with labour movement. This is followed by a brief look into the problem of existing health arrangements in irrigation schemes. Some attempt is then made to examine the advantages and disadvantages of existing organizations including those of Kenya, and finally a presentation is made of proposal that is presently under consideration in Ethiopia.

MAJOR WATER RESOURCE DEVELOPMENT PROJECTS AND SEASONAL WORKERS IN ETHIOPIA

The major water resource development projects of Ethiopia are found in the Awash Valley. Next to the Blue Nile, Awash is the largest river in Ethiopia. Located in the southern and eastern part of the central plateau of the country (figure 1), between latitudes 8° North and 12° North, the Awash basin covers an area of about 120 000 km^2, of which about 175 000 ha. are irrigable and 400 000 ha. pastoral lands. The source of the river lies about 90 km west of the capital city at an altitude of3 000 m and it ends up in the north eastern part of the country at 250 m elevation. The total length of the river is estimated at 1200 km. The valley is conveniently divided into three zones - the Upper Valley extending 120 km from Koka dam to Metahara, the Middle Valley stretching over 680 km from Metahara to Tendaho, and the Lower Valley, 205 km from Tendaho to Lake Abbe. The Upper Valley ranges in altitude between 1 500 and 970 m. Its agricultural area consists of 15 423 ha. of sugar cane plantations at Wonji and Metahara, and 6433 ha. of fruit, vegetable and cotton farms at Tibila, Mertijeju and Nura Era. The Middle Valley lies at altitudes ranging from 970 to 385 m. It includes 21 522 ha. of farms devoted mainly to cotton. The main cotton farms of Tendaho, Mille and Assayita in the Lower Valley cover an area of13 490 ha.

All irrigation projects described above are State-owned. The sugar estates of Wonji and Metahara are run by a sugar corporation of the Ministry of Industries, while all remaining farms are managed by the Ministry of State Farms. The managementof the latter farms is divided into the Horticultural Corporation, the Middle Awash Corporation and the Lower Awash Corporation. Each corporation is again divided into enterprises and unit farms.

The population of the area includes semi-nomadic pastoralists, newly settled nomads, and permanently settled and migrant labourers from the highlands. As shown in Table 1, the total population fluctuates seasonally depending upon availability of work. Practically all farms have seasonal workers. Cane cutting, cotton picking and fruit collection are usually done by seasonal labourers. There are more permanent than seasonal residents on the Wonji and Metahara sugar estates and the Melka Sadi banana plantations (Table 1). This is attributed by Kloos (1977) to the fact that sugar cane and banana cultivation are labour-intensive throughout the year, whereas

cotton growing requires a large labour force only during the picking season. Cane cutters, however, stay in the work area much longer (nine months of milling season, October to May) than those engaged in cotton picking (two to three months from October to February).

Table 1. Volume of migrant labour force in the Awash Valley in Ethiopia; total population seasonal and permanent labour force combined is at least 196 678.
* indicates that information is not available.

Farm area	Hectares	Major crops	Population			
			seasonal	permanent	settled families	Total
UPPER AWASH						
1. Wonji and Shoa	7 000	Sugar cane	*	30 000		30 000
2. Metahara	8 423	Sugar cane	4 664	20 695		25 359
3. Tibila	1 167	Fruits & vegetables	1 500	2 935		4 435
4. Merti Jeju	1 956	Fruits & cotton	1 350	4 790		6 140
5. Nura Era	3 310	Fruits & cotton	2 750	6 080		8 830
Total Upper Awash	21 856		10 264	64 500		74 764
MIDDLE AWASH						
1. Melka Sadi	2 833	Banana & cotton	4 654	5 175		8 829
2. Melka Werer	3 677	Cotton	2 065	1 275		3 340
3. Ambash	2 437	Cotton	2 500	9 785		12 285
4. Older Amibara	1 700	Cotton	2 750	7 350	2 205	12 305
5. Newer Amibara	7 145	Cotton	*	*		*
6. Bolhamo	*	Cotton	*	*		*
7. Halidebe	*	Cotton	*	*	*	*
8. Meteka	2 081	Cotton	3 000	10 355		13 355
9. Gewani	400	Cotton	384	*	3 040	3 424
No totals can be given for Middle Awash due to insufficient data available						
LOWER AWASH						
1. Mille	990	Cotton	698	3 320		4 018
2. Tendaho-Dubti	6 436	Cotton	3 000	5 705	9 165	17 870
3. Tendaho Dit Bahri	6 947	Cotton	9 702	3 230	4 100	17 032
4. Assayita	1 917	Cotton	1 500	19 245	2 966	29 456
Total Lower Awash	16 290		14 900	31 500	16 231	68 376

Source: Water Resources Development Authority, 1984.

The migrant agricultural workers for the Upper and Middle Awash usually come from the ethnic groups of Kembata, Hadya and Wollamo in southern Ethiopia. The majority of migrant labourers in the cotton farms of the lower valley come from the northern provinces of Wello and Tigrai.

MAJOR VECTOR-BORNE DISEASES IN THE AWASH VALLEY

The main vector-borne diseases in the Awash Valley are schistosomiasis and malaria. According to the 1980-1981 report of the National Malaria Control Programme, the prevalence of this disease in the Middle Awash Valley is 6.7%, a level which exceeds the critical national level of 5%. Medical records in the area indicate that malaria is heading the list of the ten most common diseases in the valley (Water Resources Development Authority, 1984). Although cases of *Plasmodium malariae* are occasionally encountered, *P. falciparum* and *P. vivax* are the predominant species in the valley. *Anopheles gambiae*, *A. arabiensis*, *A. pharoensis* and *A. funestus* are the species serving as vectors of the disease in the valley.

Both intestinal and urinary schistosomiasis occur in the Awash Valley. *Schistosoma mansoni* is well established in the sugar estates of Wonji and Metahara as well as the other farms in the Upper Valley. The prevalence of this disease in Wonji has been continuously on the rise since the establishment of the sugar plantation in 1950. In 1966, the parasite was recorded from only three children (Bruijning, 1969). The Wonji hospital laboratory report for 1979 indicated over 300 cases; about 4% of all hospital admissions in 1982 were due to this disease (WRDA, 1984).

Biomphalaria pfeifferi is the only intermediate host of *S. mansoni* in the valley, and this species has been found breeding most profusely in tertiary and drainage canals where the water velocity is the lowest and aquatic vegetation most abundant.

S. haematobium is endemic in limited and restricted foci both in the Middle and Lower Awash Valley. No *S. haematobium* transmission nor any live intermediate host has been found south of the Melkawarer village. Transmission occurs only in the clear marshy waters of swamps in undeveloped flood plains (Brown, 1980). Infection rates as high as 60% (Lemma, 1969) and intensity of infection as high as 1417 eggs/10ml urine (Meskal *et al.*, 1985) have been reported from the Middle Awash Valley.

The Malaria Control Programme sprays all living quarters in the Valley with DDT twice a year. The timing of spraying operations is based on the mosquito breeding season immediately following the two rainy seasons of the country. Chemoprophylaxis is also given, but compliance is low. With regard to schistosomiasis control only sporadic efforts have been made in the past few years, usually initiated by interested private individuals with no sustained effort by established organizations. Research workers in the Institute of Pathobiology have on several occasions launched the control of *S. mansoni* in Wonji and a nearby Tensae Berhan, but there has been no follow-up or evaluation.

A recently established inter-institutional collaborating group has shown an interesting result in the management of water-related health and environmental problems by pooling together human and material resources from organizations and government institutions with divergent mandates.

DISSEMINATION OF MAJOR VECTOR-BORNE DISEASES IN RELATION TO LABOUR MOVEMENT IN THE AWASH VALLEY

The migrant labour force coming from the highlands of Tigray, Wello and northern Shoa provinces have little resistance to malaria and very easily succumb to this disease as they go down to the Awash Valley for cotton picking and other activities. The bi-annual spraying of

DDT does not seem to provide the expected full protection. The spray time and frequency was determined several years before the establishment of irrigation schemes in the valley. No conclusive study has yet been made on the extent to which canal waters contribute to the mosquito population, and hence to malaria transmission. We are not also sure of the efficacy of DDT sprayed to walls of temporary abodes of the migrant labourers.

With regard to schistosomiasis, health records show that before the development of sugar estates in Ethiopia, practically no case was detected outside the provinces of Harar, Tigray and the Lake Tana basins of Gojjan and Gondar (Schaller and Kuls, 1972). These authors also anticipated that "new biotopes of water snails developing in the wake of modernization of agriculture and migration of people from endemic areas of schistosomiasis into prospective industrial areas could favour the introduction and spread of *Schistosoma* species pathogenic in man". In the past several years, the northern provinces of Wello and Tigray have been seriously affected by drought, over-grazing and land exhaustion. As a result, the inhabitants have been migrating southwards in search of employment. As indicated earlier, the majority of seasonal labourers in the Awash Valley come from these provinces. It ishighly plausible therefore that *S. mansoni* was introduced first to Wello from Tigray by the migrant labour force that had to pass through this province, and that newly infected people from Wello and their compatriots from Tigray introduced the disease to Wonji. Seasonal workers coming from the southern districts of Wolayita, Hadya and Kembata may have picked the newly introduced diseases from the sugar estates of Wonji and Metahara and disseminated it in their districts.

HEALTH ARRANGEMENTS IN ETHIOPIAN IRRIGATION DEVELOPMENT SCHEMES

Government agencies responsible for individual irrigation projects provide health services as part of their development concerns, but the health services are limited to treatment of sick individuals with little attention to sanitation, environmental protection or vector control. Thus, there are clinics in farm units to provide immediate medical care for injuries encountered in the field, health centres at the level of enterprises and corporations to provide medical care to sick farm workers and relatives living with them. The sugar estates to Wonji and Metahara and the Lower Awash Corporation also have hospital services. According to a recent report by the WRDA (1984), there are in the whole valley four medical doctors,12 health officers, 29 nurses, three sanitarians, 13 laboratory technicians, three x-ray technicians and 167 health assistants. The annual health budget for all units is close to 4.5 million Birr (about US$2.2 million); 44% of this budget goes to salaries, 33% to drugs and equipment and 23% for referral cases and other costs. There is no indication of any provision for preventive activities. No medical screening is done of seasonal workers, there are no adequate and acceptable sanitary facilities, neither for permanent nor temporary workers, who are often seen defecating in the field rather than in the poorly constructed and ill-maintained latrines, and water supply is poor in most labour camps so that most workers use the water directly from the canals. According to the above referred report, "most of the diseases prevalent in the Awash Valley could be effectively controlled, if not eliminated, through improved hygiene. The chain of transmission of diseases like schistosomiasis and dysentries could be broken if people would use simple latrines and would avoid contact with contaminated waters".

One of the reasons for negligence of disease prevention in water resource development is perhaps the absence of a strong link between the Ministry of Health and the development agencies. Health workers in irrigation projects are immediately responsible to farm enterprise man-

agers who have little appreciation of the prevention and control of diseases. The main concern of most managers appears to be immediate and maximum farm output with the minimum possible input, and health service is usually regarded as a necessary evil, which is easily dealt with by providing the clearly visible curative service. It is not hard to visualize difficulties of non-health officials to predict the longterm advantages of disease prevention and control. This is even more so in the absence of any department in the Ministry of Health concerned with health problems in water development projects.

There is now a new institutional arrangement by which health and environmental protection receive due consideration in the planning and operation of water development projects. This responsibility is given to the Public and Environmental Health Unit of the Water Resources Development Authority. According to the organizational structure of the WRDA, some of the powers and responsibilities of the health unit include:

- identification of the possible health hazards accompanying specific water development projects;

- providing necessary technical advice on the design and construction of water resources development schemes so as to minimize the incidence of water-related diseases.

- investigation into the prevention of water-related diseases and advising water resource development project management on establishing health facilities including disease control measures, and following up on the implementation.

We have shown earlier that health services planned and managed by development agencies without any inspection from the Ministry of Health are not very effective. Such an organizational arrangement lacks in appropriate health policy, proper planning and appropriate technology for the incorporation of health safeguards in water resources development projects.

The Public and Environmental Health Unit in the WRDA of Ethiopia has an important role to play in the prevention of health hazards in water resource development projects. It attempts to point out possible health problems in planned projects, and suggests methods of overcoming such problems before and during implementation. In the initial stages of development in any water schemes, there is usually a congenial cooperation between the health unit and development agencies. But once the project is completed and handed over to the State Farms, it becomes almost impossible to enforce health measures other than curative services. We have witnessed in the past few years that it was easy to convince the newly developing irrigation project at Amibara to invest several thousand dollars in the construction of a drainage canal to divert agricultural waste water back to the river. On the other hand the Committee for Inter-institutional Collaboration (CIC) and the health unit of WRDA were not able to convince the Ministry of State Farms to put one in a few hundred dollars toward draining a small pool of waste water in one of its old farms. This problem cannot be unique to Ethiopia. In the Philippines for example, ''drainage channels, constructed as part of the schistosomiasis control programme, are not maintained '' (see: paper by Tech pages 52-69). It appears that the interest in health shown by development agencies during the early phase of construction arises out of the desire to please such financing agencies as the World Bank and UNDP who insist on measures against health hazards arising from projects financed by them.

Because of its relatively low position in the administrative hierarchy of the government structure, the health unit in the WRDA lacks the legal and administrative power to enforce health regulations upon such powerful authorities as the Ministry ofAgriculture and the Ministry of Industries.

It is essential to establish organizational arrangements to ensure proper implementation of health safeguard measures in water resource development projects in view of the fact that:

❒ The future of such under-developed tropical countries as Ethiopia lies in developing still more water-related agriculture and power supply;

❒ development of water resources is often accompanied by mass movement of people from different parts of the country;

❒ vector-borne diseases are easily introduced in water development projects by migrant labour force, and

❒ other water-related diseases could easily establish themselves in such areas,

ALTERNATIVE INSTITUTIONAL ARRANGEMENTS

In order to come up with suitable institutional arrangements for the development and implementation of health policies in water resource development projects, it may help to outline the functions expected of such an arrangement, and to identify shortcomings of existing relevant organizations.

Health and environmental safeguard measures in water resources development projects should include:

❒ establishing appropriate health policies for such projects;

❒ undertaking or ensuring the undertaking of research designed to predict health problems arising from individual projects;

❒ providing technical health advice to water resource development authorities in their feasibility studies;

❒ providing guidelines on the type, number and function of health service institutions within projects;

❒ undertaking regular surveillance of the health status in and around project areas;

❒ supervising health activities in project areas and ensuring compliance with health policies and plans;

❒ providing the necessary manpower to ensure implementation of health programmes in water resource development projects.

The National Irrigation Board and the Ministry of Industries in Kenya as well as the Ministry of State Farms and the Ministry of Industries in Ethiopia appear to have an understanding that they should provide a health service in their respective water resource development projects. They do in fact allocate substantial amounts of money for the purpose. But, looking at the above list of essential elements and comparing it with the activities of these bodies, there can be no doubt that they lack proper orientation in health service arrangements, and also suffer from shortage of necessary manpower and adequate tools to carry out health impact assessment. The Public and Environmental Health Unit of the WRDA in Ethiopia and the Interministerial Committee in Kenya appear to have a clearer concept of what needs to be done in order to mitigate health impact of water resource development, but they do not have the necessary manpower nor the legal authority to enforce their recommendations. The Committee for Inter-institutional Collaboration in Ethiopia has a clear understanding of what needs to be done to avert negative health impact of water development schemes, and has the necessary manpower. But it is not yet a legally constituted body and does not also have the material resource to implement its recommendations.

From what we see above, each of the arrangements mentioned for Ethiopia has its own merits. It is therefore essential not to interfere too much with their existing organizational arrangements. But, since the legal power to develop any health policyand enforce it upon other institutions of Ethiopia lies within the Ministry of Health and since the allocation of necessary health personnel is also within the purview of this Ministry, it is recommended to make such organizational arrangements that all the above-mentioned mechanisms are served effectively by this Ministry. Since all organizations concerned with health safeguards of water resource development are already brought together in the CIC, formally establishing this Committee on a permanent basis and providing it with a secretariat in the Ministry of Health could cover most, if not all, health deficiencies that exist in water resources development projects.

REFERENCES

Roundy

Amin, M. 1984. Human population movements and their impact on transmission and control of schistosomiasis in irrigation schemes in the Sudan, in: *Proceedings of the Workshop on Human Population Movements and their Impact on Tropical Disease Transmission and Control*, Malcolm A. Fernando (ed.), Peradeniya, Sri Lanka.

Anderson, J.N., 1982. Rapid rural 'development' performance and consequences in the Philippines, in: *Too Rapid Rural Development: Perceptions and Perspectives from South-East Asia*, Colin MacAndrews and Chia Lin Sien (eds.), Ohio University Press, Athens, Ohio.

Bahrin, T.S., C. McAndrew and K.S. Sandhu, 1983. Land development in Melaka: the case of Kemendor, in: *Melaka: The Transformation of a Malay Capital c. 1400-1980, vol. 2*, K.S. Sandhu and P. Wheatley (eds.), Oxford University Press.

Bromley, R., 1980. The colonization of humid tropical areas in Ecuador, in: *Land, People and Planning in Contemporary Amazonia*, Francoise Barbira-Scazzocchio (ed.), Centre of Latin American Studies Occasional Publication No. 3, Cambridge University Press.

Causey, O.R., and C.E. Causey, 1974. Transmissible diseases in the Brazilian Amazon, in: *Man in the Amazon*, Charles Wagley (ed.), University of Florida Press, Gainesville.

Chambers, R., 1969. *Settlement Schemes in Tropical Africa: a Study of Organization and Development*, Frederick A. Praeger, New York.

Chambers, R., 1970. Introduction, in: *The Volta Resettlement Experience*, R. Chambers (ed.), Praeger Publishers, New York.

Colson, E., 1971. The Social Consequences of Resettlement: the Impact of the Kariba Resettlement upon the Gwemba Tonga, Kariba Studies IV, Manchester University Press.

Crist, R.E., and C.M. Nissly, 1973. *East from the Andes: Pioneer Settlements in the South American Heartland*, University of Florida Press, Gainesville.

Crossley, J.C., 1985. Innovations in colonising Bolivian Amazonia, in: *Change in the Amazon Basin. Volume II: The frontier after a decade of colonisation*, John Hemming (ed.), Manchester University Press.

Dickenson, J.P. et al., 1983. *A Geography of the Third World*, Methuen, London.

Farmer, B.H., 1957. *Pioneer Peasant Colonization in Ceylon: A Study in Asian Agrarian Problems*, Oxford University Press.

Farmer, B.H., 1974. *Agricultural Colonization in India Since Independence*, Oxford University Press.

Fenwick, A., A.K. Cheesmond, M. Kardaman, M.A. Amin, and B.K. Manjing, 1982. Schistosomiasis among labouring communities in the Gezira irrigated area, *Sudan. J. Trop. Med. Hyg., 85*: 3-11.

Goldsmith, E., and N. Hillyard, 1984. *The Social and Environmental Effects of Large Dams*, Volume I: Overview, Wadebridge Ecological Centre, Camelford, Cornwall, U.K.

Hunter, J.M., 1980. Strategies for the control of river blindness, in: *Conceptual and Methodological Issues in Medical Geography*, Melinda S. Meade (ed.). Studies in Geography No. 15, Department of Geography, University of North Carolina at Chapel Hill.

Imevbore, A.M.A., 1975. The Kainji Dam and health, in: *Man-Made Lakes and Human Health*, N.F. Stanley and M.P. Alpers (eds.). Academic Press, London.

Johnson, S.H., 1982. The effects of a major dam construction: The Nam Pong Project in Thailand, in: *Too*

Rapid Rural Development: Perceptions and Perspectives from South-East Asia, Colin MacAndrews and Chia Lin Sien (eds.), Ohio University Press, Athens, Ohio.

Kloos, H., 1985. Water resources development and schistosomiasis ecology in the Awash Valley, Ethiopia, *Soc. Sci. Med. 20*: 609-25.

Korte, R., 1973. Health and nutrition, in: *Mwea: an Irrigated Rice Settlement in Kenya*, R. Chambers and J. Moris (eds.), IFO-Institute für Wirtschaftsforschung München, Afrika-Studienstelle 83, Weltforum Verlag, Munich.

MacAndrews, C., H.B. Fisher, and A. Sibero, 1982. Regional development, planning and implementation in Indonesia: The evolution of a national policy, in: *Too Rapid Development: Perceptions and Perspectives from South-East Asia*, Colin MacAndrews and Chia Lin Sien (eds.), Ohio University Press, Athens, Ohio.

Macdonald, G., 1955. Medical implications of the Volta River Project. *Trans. Roy. Soc. Trop. Med. Hyg. 49*: 13-27.

Meade, M.S., 1974. *Changing Health Environments through Land Development: the Case of the Federal Land Development Authority in Peninsular Malaysia*, Ph.D. dissertation in Geography, University of Hawaii, Manoa.

Meade, M.S., 1978. Community health and changing hazards in a voluntary agricultural resettlement, *Soc. Sci. Med. 12D*: 95-102.

Moris, J. 1973. The Mwea environment, in: *Mwea: An Irrigated Rice Settlement in Kenya*, R. Chambers and J. Moris (eds.), IFO-Institut für Wirtschaftsforschung München, Afrika-Studienstelle 83, Weltforum Verlag, Munich.

Moran, E.F., 1981. *Developing the Amazon*, Indiana University Press, Bloomington.

Moran, E.F., 1983. Government-directed in the 1970s: an assessment of Transamazon Highway colonization, in: *The Dilemma of Amazonian Development*, Emilio F. Moran (ed.), Westview Press, Boulder, Colorado.

Moran, E.F., 1985. An assessment of a decade of colonisation in the Amazon Basin, in: *Change in the Amazon Basin.* Volume II: The Frontier after a decade of colonisation, John Hemming (ed.), Manchester University Press.

Ortiz, S., 1980. The transformation of Guiviare in Columbia: Immigrating peasants and their struggles, in: *Land, People, and Planning in Contemporary Amazonia*, Francoise Barbira-Scazzochio (ed.), Centre of Latin American Studies Occasional Publication No. 3, Cambridge University Press.

Roundy, R.W., 1978. A model for combining human behavior and disease ecology to assess disease hazard in a community: rural Ethiopia as a model, *Soc. Sci. Med. 12D*: 121-30.

Saunders, J., 1974. The population of the Brazilian Amazon today, in: *Man in the Amazon*, Charles Wagley (ed.), University of Florida Press, Gainesville.

Schuurman, F.J., 1980. Colonization policy and peasant economy in the Amazon Basin, in: *Land, People and Planning in Contemporary Amazonia*, Francoise Barbira-Scazzochio (ed.), Centre of Latin American Studies Occasional Publication No. 3, Cambridge University.

Scudder, T., 1975. Resettlement, in: *Man-Made Lakes and Human Health*, N.F. Stanley and M.P. Alpers (eds.), Academic Press, London.

Scudder, T., 1981. *The Accelerated Mahaweli Programme (AMP) and Dry Zone Development: Some Aspects of Settlement*, Report no. 3, Institute for Development Anthropology, Binghamton, New York.

Smith, N.J.H., 1981. Colonization lessons from a tropical forest, *Science 214 (4522)*: 755-61.

Smith, N.J.H. 1982. Rainforest Corridors: The Transamazon Colonization Scheme, University of California Press, Berkeley.

Stearman, A.M., 1983. Forest to pasture: Frontier settlement in the Bolivian lowlands, in: *The Dilemma of Amazonian Development*, Emilio F. Moran (ed.), Westview Press, Boulder, Colorado.

Stewart, R., 1967. Japanese Colonization in Eastern Paraguay. *Foreign Field Research Program sponsored by the Office of Naval Research Report No. 30, Publication 1490*, National Academy of Science, National Research Council, Washington.

Townsend, J., 1985. Seasonality and capitalist penetration in the Amazon Basin, in: *Change in the Amazon Basin*. Volume 2: The frontier after a decade of colonisation, John Hemming (ed.), Manchester University Press.

Weil, C., 1981. Health problems associated with agricultural colonization in Latin America, *Soc. Sci. Med. 15D*: 449-61.

Meskal

Bos, R., 1984. *Status of institutional arrangements in relation to the incorporation of health and environmental safeguards in water resources development projects in two selected African countries*, unpublished working paper, EPO/PE/WP/84.6, WHO, Geneva.

Bradley, D.J., and Webbe, G., 1975. Ecological and habitat methods in schistosomiasis control, *Proc. Int. Conf. Schisto.*: 691-706.

Brown, D.S., 1980. *Freshwater snails of Africa and their medical importance*, Taylor and Francis, London.

Bruijning, C.F.A., 1969. Bilharziasis in irrigation schemes in Ethiopia, *Trop. Geogr. Med. 21*: 280-292.

Kloos, H. 1977. *Schistosomiasis and irrigation in the Awash Valley of Ethiopia*, Ph.D. Dissertation, Department of Geography, University of California, Davis, California.

Lemma, A., 1969. Bilharziasis in the Awash Valley. I. An epidemiological study with special emphasis on its possible future economic and public health importance, Ethiop. Med. J. 7: 147-176.

McMullen, D.B, Z.J. Buzo, M.B. Rainey, and J. Francotte, 1962. Bilharziasis Control in relation to water resources and development in Africa and the Middle East, *Bull.Wld.Hlth.Org. 27*: 25-40.

Meskal, F.H., T. Woldemichael and M. Lakew, 1985. Endemicity of urinary schistosomiasis in Enta-doyta village, Gewane flood plain, Eastern Ethiopia. *Ethiop. Med. J. 23*: 107-115.

Obeng, L., 1977. Should dams be built? The Volta Lake example, *Ambio 6*: 46-70.

Schaller, K.F. and W. Kuls, 1972. Ethiopia. A Geomedical Monograph, Springer Verlag, Berlin.

Water Resources Development Authority, 1984. *Report on Public and Environmental Health Status in Irrigated Agricultural Areas of the Awash Valley*, Mimeographed document, WRDA, Addis Ababa.

Wright, W.H., 1972. A consideration of the economic impact of schistosomiasis, *Bull.Wld.Hlth.Org. 47*: 559-566.

Additional references

Gratz, N.G., 1987. The effect of water development projects on malaria and malaria vectors in Turkey, in: *Effects of Agricultural Development on Vector-borne Diseases*, FAO document AGL/MISC/12/87, Rome.

Marsden, P.D., 1984. Selective Primary Health Care: strategies for control of disease in the developing world: VI Chagas' Disease. *Reviews of Infectious Diseases 6*:6.

Waiyaki, P.G., 1987. The history of irrigation development in Kenya and the associated spread of schistosomiasis, in: *Effects of Agricultural Development on Vector-borne Diseases*, FAO document AGL/MISC/12/87, Rome.

Zeledon, R., 1981. *El* Triatoma dimidiata *y su relacion con la enfermedad de Chagas.* Editorial Universidad Estatal a Distancia, San José, Costa Rica.

WHO FAO UNEP
PEEM 1986

FINANCIAL AND ECONOMIC ASPECTS OF ENVIRONMENTAL MANAGEMENT, AND ITS COST-EFFECTIVENESS AS A VECTOR CONTROL MEASURE

"The successful promotion of environmental management for vector control depends on persuading financing bodies (...) of the desirability of expending resources on environmental management. It is therefore vital to consider the motivation (of financing bodies) how they perceive water and other resources development projects and their effect on health, and how they can be persuaded to finance approaches that will prevent such projects from aggravating the extent of vector-borne diseases."

Thus starts the technical discussion section of the report of the sixth Panel meeting. At various previous discussions, the crucial role of financial decision makers in ensuring the incorporation of health safeguards in resource development projects had been emphasized. It had also become clear that issues of cost-effectiveness of environmental management, as compared to chemical and biological control, needed sorting out.

Planners of resource development projects are faced with increased difficulties in justifying the expenditures in the light of future economic returns. This subject is elaborated on in connection with irrigation development in the first paper in this section, by Mather. At the central planning level any additional capital investments with no direct economic benefits to the sector in question (such as environmental management measures for vector control) will be frowned upon, particularly in countries with an already substantial external debt. On the other hand, the decision to exclude a budget for engineering modifications favouring the health condition will with certainty lead to a burden on the health sector, which may then have to use scarce foreign currency on a recurrent basis to import, for example, insecticides. The technical discussion section of the report introduces the reader to the economic concepts of discount rates, shadow pricing and opportunity costs and the weight they carry in selecting the most appropriate alternative. The role of the farmer in covering the operation and maintenance (including environmental management) costs of irrigation schemes is discussed by Small in the second paper.

In many endemic countries, managers of vector control programmes have to make informed decisions on integrated vector control strategies, in order to achieve an optimal balance between its components. Cost-effectiveness analysis is the most appropriate tool in this context, and the principles of this analysis were addressed in the second half of the discussion. A review of cost-effectiveness studies on environmental management and other vector control approaches was prepared by Mitchell and is presented here as the third paper. This is followed by Mills' and Bradley's paper which takes the issue into a broader epidemiological and health care context.

Two major recommendations were made by the Panel as a result of the discussion:

(1) The use of environmental management methods to limit the possible exacerbation of vector-borne diseases should be considered in the financial appraisal of water resource development projects.

(2) Cost-effectiveness analysis should be used to identify the most appropriate means of vector control; cost-effectiveness studies should adopt a standard methodology, considering epidemiological, entomological, behavioural and capital vs. recurrent cost issues.

The implementation of the second recommendation is now underway, with the preparation of the guidelines for cost-effectiveness studies on integrated vector control operations by Anne Mills and Margaret Phillips of the Evaluation and Planning Centre of the London School of Hygiene and Tropical Medicine.

FINANCIAL CONSTRAINTS ON AND INCENTIVES FOR THE IMPLEMENTATION OF ENVIRONMENTAL MANAGEMENT FOR VECTOR CONTROL IN IRRIGATION PROJECTS

by

T.H. Mather

INTRODUCTION

Before considering the introduction of environmental management measures for vector control in irrigation projects, indeed before even considering any kind of measures aimed at the protection or promotion of human health, it is first necessary to be aware of the vast range of physical, social and economic conditions under which irrigation is applied, and the actual or potential impact of these conditions on the health of the associated community. There will be circumstances where such an impact is minor, as for example in cases where the project causes little change in the overall vector habitats, population migration patterns and other demographic characteristics, labour and leisure activities. On the other hand, irrigation development may create major changes in the hydro-ecological status of a given area, and may cause movement of either non-immune, susceptible groups of people into endemic areas, or of disease carriers into non-endemic areas, and may thus also contribute to the spread of certain genetic traits of pathogens, such as drug-resistance. Moreover, these phenomena may be accompanied by socio-economic activities which increase the level of exposure to disease risk.

The former case, typified by small schemes, probably in humid and sub-humid areas, does not present very obvious justifications for on-scheme investments in vector control through environmental measures. The latter may do so, but even where the benefits from intervention can be clearly perceived, the mobilization of finance for this purpose faces competing demands for more directly productive uses. Attempts to secure investment in health protection in irrigation must therefore satisfy two requirements. They must confirm the feasibility and effectiveness of the proposed measures and they must already define their benefits to the community.

FINANCIAL CONSTRAINTS

The problems of finance within the context of irrigation vary widely throughout the world. This is illustrated in table 1, showing a range of typical costs for the more formal, generally medium to large irrigation schemes.

In regions with high cost characteristics, the further loading of these costs for health protection is likely to be resisted, at least on the part of the investor. There are, however, strong protagonists of the move for greater emphasis on human and social concerns in irrigation. This

At the time of preparation of this paper Mr Mather was Chief, Water Resources Development and Management Service, FAO, Rome; he retired from that position in 1986.

was shown at the FAO Consultation on Irrigation in Africa, held in Lomé, Togo in April 1986 (FAO, 1986). The 41 countries represented at this consultation accepted the need for economic viability of irrigation projects in order to ensure their sustained productivity but they emphatically insisted on the need for additional evaluation criteria which would guarantee the incorporation of human, social and cultural issues.

This change in emphasis can be expected, eventually, to influence investment policies on the types of projects to be supported but it may not lead to direct investment in health aspects unless these can be shown to have economic advantages.

Table 1. Typical costs of irrigation development, 1980 prices

Region	Gravity schemes US$/ha	Gravity schemes Share in Total %	Pump and tubewells US$/ha	All schemes Weighted Average Cost US$/ha
Latin America	6 000	50	3 000	4 500
Near East	7 000	70	4 000	6 100
Africa (excl. Sudan)	11 000	70	6 000	9 500
Sudan	5 000	50	4 000	4 500
Asia and Far East (excl. South Asia)	4 000	60	2 000	3 200
South Asia (Bangladesh, India, Pakistan)	2 500	40	1 000	1 600

Rehabilitation in all regions except South Asia - US$1 760/ha

Rehabilitation in South Asia - US$ 800/ha

Source: FAO (1982)

The problems of demonstrating such advantages were brought out by the WHO Workshop on Economic Aspects of Parasitic Diseases, organized by the UNDP/World Bank/WHO Special Programme on Research and Training in Tropical Diseases (WHO/TDR, 1986). This workshop gave prominence to five vector-borne diseases, malaria, schistosomiasis, filariasis, trypanosomiasis and leishmaniasis. All five of these respond to environmental control through engineering or other site modification, water supply and sanitation, or improved housing, in addition to the causing organisms and their vectors being susceptible to drugs or pesticides. The workshop drew attention to the complex and site-specific nature of disease transmission and, in the paper *The economics of parasitic diseases: research priorities* by Rosenfield *et al.*, it is noted:

> "In attempting to analyse the economic consequences of parasitic diseases and the economics of their control, economists have usually relied on the tools of cost-benefit analysis, cost-effectiveness analysis and financial analysis. The results have been subject to considerable criticism because of conceptual and methodological problems. For example, most studies have not taken into account the epidemiology and natural history of the disease in estimating the associated economic losses, thereby leading to inappropriate conclusions."

The foregoing remarks are applicable to all forms of disease control. When environmental measures are considered, usually within an integrated control programme, the issue of investment becomes more prominent. The use of chemotherapy and pesticides will already form an accepted part of a routine health programme. Therefore, its expansion to an irrigation scheme, while presenting an added cost, can probably be absorbed without great difficulty as a charge on a broader community. The application of environmental modification or manipulation to the scheme, in contrast, introduces costs which are identifiable with the project itself either in the form of increased capital requirements for structures and conveyance systems or added costs for maintenance of channels, for changes in water management practices and equipment or revised crop production practices. Similarly, the adoption of improved standards for housing, water supply and sanitation for the scheme is usually seen as a project-incurred cost, to be assessed against returns from the project.

In general then, and especially where irrigation costs are already high, the prospects of financial support for the introduction of environmental management as a vector control measure are not good. As an isolated approach, it is unlikely to be fully effective. When combined with other methods of control, be it chemical or biological control of vectors, or chemotherapy, it is virtually impossible to identify the benefits attributable to environmental management within an overall analysis which is in any case difficult to quantify. Yet, many countries throughout the world have used environmental management to great advantage for health protectionand improvement in irrigation schemes.

One of the most impressive examples is found in the multi-million dollar Blue Nile Health Project in Sudan which has the advantage of sufficient size, population and therefore economic and political importance at national level to warrant attention, and which still represents a remedial rather than an originally planned preventative approach. In irrigation schemes in China, environmental measures involving large scale community efforts have provided effective control of schistosomiasis. In the cotton-producing areas of southern Turkey, on the other hand, the deterioration of the irrigation and drainage system has given rise to malaria problems, calling for greater attention to environmental aspects and the cost of their neglect.

Agricultural and health authorities in many countries are well aware of the role of environmental management in the context of irrigation. Some, such as Ethiopia, have established special health units to work with the responsible development agencies. Designs are prepared for projects which incorporate structural and operational features to reduce vector production and for housing and settlement features to reduce transmission risks, but often the costs of construction or of continued maintenance are judged to be excessive. Economics are imposed, with the omission of many of those features which can not be clearly identified as productive.

At the level of the individual farmer, there are also numerous constraints linked to his financial status and which depend on the availability of an income in excess of the needs for subsis-

tence and as an insurance against the uncertainties and risks associated with agriculture. Again, it must be recognized that the use of any economic surplus is at the discretion of the farmer. He may prefer to give priority to investment in options other than community health, and is unlikely to give high priority to the improvement of a plot of land and a system of water supply for which he may have little security of tenure or guarantee of supply.

INCENTIVES

The primary incentive to direct financial resources toward any purpose in particular is to demonstrate the economic benefits arising from that purpose. Although the difficulties of proving such benefits from environmental management for vector control have been illustrated, it is clear that the use of environmental measures in irrigation implies an overall improvement in the management of land and water resources. This means the more disciplined, rational and economical use of those resources. These are exactly the guiding principles for the improvement of crop production in irrigated agriculture.

The planning, design, construction and operation of irrigation schemes should therefore aim to avoid problems of excess water, seepage, ponding and waterlogging which in addition to raising levels of vector production reduce crop yields. The costs associated with preventive or remedial works should then be offset against increased production. Similarly, since low standards of maintenance of any irrigation and drainage system are commonly associated with ecological conditions suited to vector production and with poor irrigation efficiencies, such features as low maintenance designs and reliable operation and maintenance procedures should be justifiable for their economic advantages while simultaneously reducing health risks.

Incentives may also arise from the potential improvements in crop production, savings in water and perhaps fuel, and reduction in labour requirements, especially in commercial schemes, resulting from changes or innovations in irrigation methods and equipment. Because of the dynamic nature of irrigated agriculture, due to changes in markets and demands, it is now necessary to adopt a concept of flexibility in planning projects and crop products. The identification of changes in crops, cropping practices and crop rotations for profitability is a valid area of research which could usefully be coupled with research into the impacts on disease vector habitats and disease transmission, to ascertain where mutual benefits can be obtained, or where potential health risks may be avoided.

At present, there is a strong trend in many countries towards the devolution of responsibility and authority for irrigation schemes from central agencies to the participating and benefiting communities. This increased autonomy offers opportunities for more active involvement of the farmers in decision-making in operations and in financial support, subject to the creation of suitable institutional arrangements for group collaboration, both internally and with external support services. With the generation of savings or the enhanced possibilities of credit and insurance, there is an improved economic climate with greater promise of surplus income. Similarly, the development of the group concept can provide the right incentive for joint activities at scheme or community level, such as routine project maintenance or improvements to settlements and services. The use of labour in this way can greatly reduce the need for direct financial intervention.

The directing of such efforts towards the objectives of environmental management for vector control, however, presupposes an awareness of the people of the causes and means of control of parasitic diseases. Quoting again from the *Economics of parasitic diseases: research priorities*:

> "Those living without access to safe water supplies, satisfactory waste disposal systems or adequate housing are at prime risk. The farmer and wage-earner face these diseases as occupational hazards. The mother/housewife and schoolchild encounter the diseases as part of everyday domestic activities. It is thus the poor, those who must come into contact with these diseases as a result of daily life and need for survival, who are at greatest risk, and at the same time are often the least informed about the means of transmission and control of these diseases.
>
> Such lack of information about the basic transmission characteristics and measures for control has profound significance for the usual type of economic analysis which assumes that rational choices are being made by informed individuals".

The incentive for community involvement through either financial or labour inputs therefore depends on generating a demand for disease prevention and control measures, including environmental management for vector control, through greater awareness of their possibilities either on-scheme or through improvements to water supplies, sanitation, housing and other community facilities. This in turn calls for an educational campaign to provide the awareness and knowledge needed to initiate and guide community choices and actions for environmental changes.

However clear may be the human and social advantages of health improvement measures, the perception of these advantages will always be most obvious to the informed, benefiting community. This group is therefore likely to be the best motivated in implementing control measures, especially where they call for environmental changes through modification of manipulation of physical factors. The local community is also best placed to provide inputs at lower cost than most external agencies, but it must first be given the ability to acquire a surplus in the form of finance, material or labour which can be applied to this objective, together with guarantees of continued access to land and a reliable supply of irrigation water.

The benefits of environmental management for vector control may be difficult to quantify, but in terms of human health, welfare and the quality of life they can, in aggregate, become a very real national asset for many countries dependent on irrigated agriculture. The greatest incentive to mobilize the potential interest and resources of the irrigation farming communities must lie in the adoption of national farm product pricing policies which will enable those communities to attain levels of income which permit the investment of resources in better working conditions, settlement, housing and services in order to ensure a healthy environment without the need for massive external financing.

CONCLUSIONS

The financial constraints on environmental management for vector control in irrigation projects are considerable. It is first necessary to define those circumstances where it may form

an effective control measure in order to justify its introduction, and even in such cases, in common with many other health promoting methods, it is difficult to assign environmental management for vector control an economic value.

In many areas, irrigation costs are already so high that any further loading is strongly resisted, although there is increasing recognition of greater human and social concern in project planning to ensure acceptability and full utilization. At the same time, there have been demonstrated benefits from environmental management for vector control on many schemes in various countries, but its promotion can be effective only where it is of perceived value to both the funding agency and the farming community.

The most promising forms of incentives are those which offer increased production and profit through improved or modified land and water management and cropping practices, while at the same time providing effective vector control.

The current trend toward greater devolution of responsibility and authority for irrigation schemes to the farming community suggests an alternative line of incentive, given the necessary information on disease causes and measures for control. But for the community to participate in the implementation of environmental management for vector control it must first be enabled to attain the necessary level of prosperity through the medium of appropriate crop pricing policies, and be assured of security of land tenure and reliability of water supply.

IRRIGATION FINANCING POLICIES TO PROMOTE IMPROVED OPERATIONS AND MAINTENANCE: THE ROLE OF THE FARMER

by

Leslie E. Small

INTRODUCTION

Over the past several decades, governments in many countries have made large investments to build, rehabilitate, and upgrade irrigation facilities. Concomitant with the increase in irrigated area has been an increase in the recurrent costs for operation and maintainance (O&M) of the irrigation facilities. This has frequently created budgetary demands that governments have found burdensome. With the economic and budgetary pressures facing many governments in the 1980s, this recurrent cost problem has received considerable attention in recent years (see, e.g., Easter, 1985; Small *et al.*, 1986; Westgate, 1985).

All too often, however, the recurrent cost problem has been addressed from a narrow perspective of how to get more from the farmers to pay for the costs of irrigation services, while overlooking the role that recurrent cost financing policies and mechanisms can play in improving the quality of irrigation services provided to the farmers.

In areas of irrigated agriculture, good O&M, particularly maintenance, is consistent with, and may often be necessary for, effective environmental management for vector control. The question of how arrangements for financing the recurrent costs of irrigation can encourage improvements in O&M is thus important and relevant to the promotion of environmental management.

POTENTIAL EFFECTS OF IRRIGATION FINANCING ON O&M

Irrigation financing mechanisms may create conditions favourable to enhancing the efficiency of system operation through their effects on (a) the availability of funds for O&M; (b) the accountability of system managers; and (c) the extent water users cooperate and are involved in O&M. In addition, it is commonly thought that financing mechanisms which require farmer payments will lead to an increase in the efficiency of water use by individual farmers; however, as noted in the section on irrigation financing mechanisms, the conditions necessary for this to occur seldom exist in gravity irrigation systems in Asia.

Availability of funds for O&M. The efficient operation of irrigation facilities is frequently hindered by low funding levels for routine O&M. If funds are allocated through a government budgetary process, it is likely, especially during periods of generally tight budgets, that the amounts provided for O&M will be inadequate for satisfactory performance. Alternatively, funding for O&M may be based on charges paid by water users, so that the level of funding for

Dr Small is an agricultural economist and Associate Professor at Cook College, Rutgers University, New Brunswick, New Jersey, USA

O&M can be made independent of general government budgetary constraints. If this results in increased funding for O&M, a significant improvement may be possible in the performance of existing irrigation facilities.

Accountability of system managers. Financing policies have the potential to enhance irrigation performance by increasing the degree to which irrigation managers are financially accountable to water users. If an irrigation agency receives a considerable portion of its funds from the farmers to whom it is providing water, the agency's managers are more likely to be concerned about the quality of irrigation services provided in order to enhance their ability to collect the user charges. Furthermore, water users may realize that the quality of services they receive depends on their payment of irrigation charges.

Cooperation and involvement of water users in O&M. Water users may cooperate more actively in O&M if financial policies cause them to feel that they, rather than some remote government agency, own the irrigation facilities. To encourage this, a government might provide a mechanism for the water users to agree, in advance, to accept a clearly defined financial responsibility for a position of the capital costs. For such a mechanism to be effective, the potential water users would need to be involved in the planning and design process.

IRRIGATION FINANCING MECHANISMS

The mechanisms which may be used to obtain resources for providing irrigation services can be categorized as water prices, irrigation service fees, taxes, implicit taxation, and secondary income. Water prices and irrigation service fees are direct financing mechanisms in that they are linked to irrigation. Taxes, implicit taxation, and secondary income are indirect mechanisms which bear little or no linkage to irrigation benefits.

Under a system of **water prices**, payments depend on voluntary purchase decisions by water users. Examples include charges based on users' requests for either the volume of water delivered, the duration of water delivery, or the number of irrigations. Because of technical and administrative difficulties associated with controlling and measuring water, pricing in gravity irrigation systems characterized by large numbers of small farmers growing irrigated rice is generally economically unfeasible, and is seldom attempted.

Irrigation service fees are compulsory charges imposed upon irrigation users on some basis fairly closely related to the amount of services provided. The most common example is a flat charge per hectare of land irrigated. Such charges are sometimes differentiated according to the number or the type of crops grown. In some cases, particularly in small, privately operated irrigation systems, the charge may be based on the size of the harvest.

Taxes are compulsory charges levied on individuals with no direct reference to any services provided. The amount levied, however, may be affected by irrigation. A good example is a general land tax based on assessments of land productivity. To the extent that increases in productivity resulting from irrigation are reflected in the land tax assessments, landowners will find that irrigation increases their tax obligation. Other types of taxes which may be indirectly affected by irrigation are taxes on agricultural inputs, and marketing and processing taxes on agricultural products produced on irrigated land.

Implicit taxation occurs when government policies cause domestic market prices of agricultural products to be below world market levels, or prices of agricultural inputs to be above world market levels. The amount of such an implicit tax paid by a farmer depends on the quantity of the product which he markets, or the quantity of the input which he purchases. As irrigation increases the quantities, the amount of the farmer's implicit tax increases.

Secondary income of an agency or organization responsible for providing irrigation services results from institutional arrangements which permit revenues to be earned from sources other than government budgetary allocations or charges levied on water users. Secondary income frequently results from leasing assets over which the organization has been given control.

THE IMPORTANCE OF INSTITUTIONAL ARRANGEMENTS

The extent to which the financing mechanisms discussed in the section above are likely to lead to improvements in systems performance is greatly influenced by how responsibilities are organized for allocating resources to irrigation; for utilizing these resources to implement irrigation services; for obtaining resources from irrigation beneficiaries; and for controlling the resources obtained from irrigation beneficiaries. The key distinction is between situations of full or partial financial autonomy and those of financial dependence (table 1). With financial autonomy, an irrigation agency has at least partial responsibility for all four processes. In particular, it has control over resources which it obtains from water users, and thereby also controls the allocation of all or most of the resources devoted to irrigation O&M. With financial dependence, an irrigation agency has no control over any funds collected from the water users, and is thus dependent on resources allocated to it through the general government budgetary process.

Financial dependence prevails in a number of countries including India (Bottrall, 1976; Pawar, 1985), Pakistan (Wolf, 1985; Bottrall, 1978a), Bangladesh (Khan, 1981), Thailand and Indonesia. Financing policy in Sri Lanka has also been one of financial dependence; recent policy changes with respect to irrigation service fees, including a provision for fees collected in a given project to be used for O&M in that project, represent, however, a move in the direction of financial autonomy (Engineering Consultants Ltd. & Development Planning Consultants Ltd., 1985).

One implication of financial dependence is that even if water charges are collected from farmers, decisions regarding the amount of funds made available and utilized for O&M are essentially beyond the control of either the users or the providers of irrigation services. A second implication is that accountability of the irrigation managers tends to be upward to the central government, with no financial linkages fostering a downward accountability between irrigation managers and the water users. Thus, with financial dependence, the extent to which farmers pay for the cost of irrigation services is of little consequence for the quality of irrigation (table 1).

Financial autonomy usually involves decentralized responsibility for irrigation services. In China, for example, irrigation districts are in principle supposed to sustain irrigation operations without reliance on external subsidies (Nickum, 1982). In practice, however, many subsidies are provided by the Government, even for regular O&M (*ibid.*). In Mexico and the United States,

local irrigation districts are financially autonomous within the structure of government rules and regulations that provide subsidies for initial construction (Adams, 1952; United States Congress, Office of Technology Assessment, 1983; World Bank, 1983). A similar situation exists for irrigation companies in France (Pelissier, 1968; Bergmann, 1984) and for irrigation cooperatives in Greece (Bergmann, 1984). Essentially the same can be said for the land improvement districts in Japan (Kimura, 1977; Kelly, 1982; Okamoto *et al.*, 1985). Irrigation associations in Taiwan follow a similar pattern (Abel, 1976; Bottrall, 1978b), although the Government may more directly supervise and control activities than do governments in the countries mentioned previously. The situation in South Korea is similar to that in Taiwan, with financially autonomous farmland improvement associations responsible for operating the irrigation facilities, but under fairly close supervision through the provincial governments and the Ministry of Agriculture and Forestry.

Centralized irrigation agencies may also be financially autonomous, although this appears to be relatively uncommon. An example occurs in the Philippines, where a semi-governmental cooperation, the National Irrigation Administration (NIA), is responsible for constructing and operating national irrigation systems throughout the country. Although the NIA has in the past received substantial funding through government subscription of capital, it is increasingly being forced to conduct its operations within the budget constraints of revenues earned from corporate activities.

Financially autonomous irrigation organizations generally impose direct charges on water users for O&M services. A component of the charge may also reflect the capital cost of initial construction. In most situations, a major portion of such costs is paid by the central government. For example, South Korean government policies involve specified subsidy rates for irrigation construction costs. As a result, the contribution of the irrigation organizations to the capital cost is small; the structure of irrigation service fees paid by the water users is, however,such that it is clear that the organizations are acquiring ownership rights in the irrigation system.

In addition to relying on direct fees from water users, financially autonomous irrigation organizations frequently have access to secondary income which can help finance irrigation activities. For example, irrigation districts in China may undertake sideline economic activities which generate income which is then used to finance irrigation services (Nickum, 1982). In Taiwan, some irrigation associations in areas undergoing urbanization have found that the conversion of previously irrigated land for non-agricultural urban uses has made some of the existing irrigation canals unnecessary. These associations have been able to sell the land onwhich these canals were located and use the proceeds to finance the cost of irrigation services (Taichung Irrigation Association, personal communication, 1985). In the Philippines, part of the funds used to finance O&M activities for the NIA are received from secondary sources including equipment rental, interest on construction funds received but not yet spent, and a management fee which NIA charges for managing the construction of new irrigation projects. In South Korea, secondary income from interest earnings, sale of water for non-irrigation purposes, and rental of assets provides, on the average, about one-fourth of the total income of the irrigation associations (Small *et al.*, 1986). In the United States, the formation of water users' organizations was encouraged by a government policy that gave the associationsrights to certain types of secondary income, such as the revenues from grazing permits and from the sale of power generated by hydropower facilities associated with irrigation reservoirs (Thompson, 1985). In Indonesia, some water users' organizations have rights to income from specified tracts of land.

Officials of the organizations are allowed to cultivate these tracts and retain the income as compensation for their services in lieu of direct payment by the water users.

One of the potential advantages of financial autonomy is that it establishes an environment favourable to the creation of financial accountability linkages between irrigation managers and water users (table 1). For example, it is reported that irrigation districts in China, unlike most economic enterprises in the state sector, are not over-staffed. The requirement that a significant portion of the district's expenditures must be provided by water users creates an incentive to limit the number of personnel (Nickum, 1982). There also appears to be some evidence that water users in China use the threat of non-payment of water fees as a leverage over management (*Ibid.*).

In the Philippines, the NIA's increased financial autonomy has led to changes in the financial procedures for O&M. More attention is now given to collecting fees from water users than was the case in the past, and systems of incentives have been established to increase the rates of fee collection. One consequence of these changes appears to be increased recognition of the importance of improving the quality of irrigation services provided to farmers, in order to enhance their willingness to pay the irrigation service fees.

FINANCIAL AUTONOMY: IMPLICATIONS FOR FARMERS

As noted in the previous section, financially autonomous irrigation agencies generally impose irrigation service fees on the farmers they serve, although the level of the fees is frequently reduced because the agency also has sources of secondary income. This raises the question of what is a reasonable level of fees that farmers can be expected to pay.

Information on communal and private irrigation systems in various countries in Asia - which are, by their very nature, financially autonomous - shows that even very poor farmers often pay quite large amounts for good quality irrigation services. In Bangladesh, it is not uncommon for a farmer to agree to pay 25% of his dry season irrigated rice crop to the owner of a nearby tubewell who supplies the water. Studies of farmer-managed irrigation systems in Nepal have revealed large amounts of cash and labour paid by farmers (Martin, 1986).

Two conclusions logically follow from these observations. First, although the payments are large, the benefits that farmers perceive they are receiving from the irrigation services must be significantly greater than these payments. Thus, even if farmers are very poor in an absolute sense, they have the ability to pay and be better off than if they did not have access to irrigation. Secondly, the farmers are willing to pay these amounts because they know that the alternative is to have no access to irrigation.

For larger irrigation projects with more direct government involvement, the institutional arrangement of financial autonomy can foster a willingness on the part of farmers to pay irrigation service fees because it helps establish the conditions whereby farmers know, at least as a group, that unless they pay, they will have no access to irrigation. The magnitude of the farmers' ability to pay fees in such projects depends on the quality of the irrigation services provided. In a recent study of five Asian countries, it was concluded that as long as irrigation facilities

were performing in a reasonably satisfactory fashion, the direct benefits accruing to the farmers would generally be large enough to enable the farmers to pay for the cost of O&M. But the study also concluded that, in most cases, the farmers could not realistically be expected to pay, in addition, for more than a small portion of the capital costs (Small *et al.*, 1986).

The institutional arrangement of financial autonomy provides the possibility of financing the recurrent cost of irrigation services not only from direct farmer payments, but also from secondary income. It may thus be possible to structure farmer payments for irrigation services in such a way that they include components for both recurrent and capital costs, while limiting the total payment to a level which is reasonable in the light of the magnitude of the benefits received. Thus, for example, irrigation service fees paid by farmers in Korea have clearly identified components for O&M and for capital costs, and the irrigation organizations are typically responsible for the full O&M costs plus repaying, to the central government, a specified small portion of the capital costs. But the average amount which farmers must pay is only about 93% of the average cost of O&M, with the difference between the amount paid by farmers and the expenditures of the organizations accounted for by secondary income (Small *et al.*, 1986). This arrangement has the triple advantage of giving the autonomous agency responsibility for funding the recurrent costs of irrigation; giving it and its farmer members clear ownership rights to the irrigation facilities; and keeping the irrigation service fees at a reasonable level relative to the benefits of irrigation received by the farmers.

As a final point, it should be noted that with financially autonomous irrigation agencies, the cash burden placed on the farmer to finance recurrent costs can often be reduced by provisions that allow direct contributions of labour for the maintenance of irrigation facilities. This type of "non-cash financing" is a common arrangement in communal or farmer-managed irrigation projects. For very poor farmers for whom cash is scarce, this may be an attractive alternative to a payment only in cash.

CONCLUSIONS

Policies for financing irrigation services can affect the management and performance of irrigation systems. More important than the specific nature of the financing mechanisms used are the institutional arrangements which establish responsibility for four key processes: allocating resources to irrigation, implementing irrigation services, collecting resources from beneficiaries, and controlling the resources collected.

If a financing mechanism is to have the potential to improve system performance through encouraging better management, a degree of financial autonomy is needed to create the potential for a link between the provision of irrigation services and the collection of and control over resources from water users. Likewise, for a financing mechanism to have the potential of improving system performance by encouraging active cooperation and involvement in O&M among water users, a degree of financial autonomy is needed to give the users a sense of ownership of the irrigation system.

In the absence of any significant degree of financial autonomy for the agencies that provide irrigation services, mechanisms for obtaining resources from the water users may be justified on

fiscal or income distribution grounds; however, it is unlikely that they will have any significant positive effect on irrigation performance.

Table 1. Summary of potential consequences for O&M of irrigation financing mechanisms

	INSTITUTIONAL CONTEXT AND FINANCING MECHANISMS						
Type of improvement in O&M	**Financial autonomy:** funds controlled by irrigation agency			**Financial dependence:** Funds controlled by non-irrigation agency; irrigation agency financially dependent on government budget allocation			
	Irrigation service	Water prices	Secondary income	Irrigation service	Water prices	Taxes	Implicit taxation
1. More efficient operation of irrigation facilities							
a. Improved funding of O&M	yes	yes	yes	no	no	no	no
b. Improved managerial and financial accountability	yes	yes	no	no	no	no	no
c. Improved involvement of water users	yes	yes	no	no	no	no	no
2. More efficient utilization water	no	yes	no	no	yes	no	no

THE COST-EFFECTIVENESS OF ENVIRONMENTAL MANAGEMENT AS A VECTOR CONTROL MEASURE

by

Carl J. Mitchell

INTRODUCTION

The WHO Expert Committee on Vector Biology and Control defined environmental management for vector control as the "planning, organization, carrying out, and monitoring of activities for the modification and/or manipulation of environmental factors or their interaction with man with a view to preventing or minimizing vector propagation and reducing man-vector-pathogen contact" (WHO, 1980). Integrated vector control can be considered as "the utilization of all appropriate technological and management techniques to bring about an effective degree of vector suppression ina cost-effective manner" (WHO, 1983a). Integrated control was the *modus operandi* of most vector control programmes prior to the advent of the use of DDT. More recently, the development of insecticide resistance by vectors, and public health and environmental concerns, have stimulated a renewed interest in the concept of integrated control.

The applicability of the three categories of environmental management for the control of disease vectors or intermediate hosts is summarized in *Environmental management for vector control* (WHO, 1980: table 2, page 1). This paper will review the cost-effectiveness of environmental management as compared to other vector control methods, with emphasis on mosquito control. No distinction will be made between pest and vector mosquito control since the same methodologies may be applicable.

A comprehensive review of 173 studies containing information on the costs, health effects, or economic effects of parasitic disease control has been re-issued recently (Barlow and Grobar, 1986). The authors consider four principal measures of cost-effectiveness: cost per person protected, per death averted, per case-year prevented, and per healthy year gained. In the context of the present paper, these criteria are more likely to be considered as part of a cost-benefit analysis rather than measures of cost-effectiveness per se.

Several problems arise when attempting to summarize cost-effectiveness data regarding environmental management for vector control. Generally, data are incomplete and, in most cases, there is no common denominator for measuring effectiveness. The problem is compounded when making comparisons between countries with different currency exchange rates, cost-of-living indices, and salary structures.

Dr Mitchell is Chief of the Vector Virology Laboratory in the Department of Health and Human Services of the Center for Infectious Diseases, Fort Collins, USA

HISTORICAL PERSPECTIVE

Early efforts to control vector and pest mosquitoes in the Americas by environmental sanitation have been reviewed (Public Health Study Team, 1976). It is impossible to estimate the amount of money saved by permanent drainage systems and other environmental measures used to control mosquitoes in the Panama Canal Zone, but the amount is enormous when considering the potential costs for repetitive insecticidal applications. In 1973, there was continuous maintenance of more than 500 miles of ditches, and drainage maintenance represented about 85% of the control effort. Elsewhere in the Republic of Panama, drainage systems in about 40 towns resulted in a decrease in the incidence of malaria from 60% in 1930 to less than 5% in 1946; subsequent further decreases in incidence were attributed largely to insecticide applications.

The success of the Tennessee Valley Authority (TVA) in controlling the malaria vector *A. quadrimaculatus*, principally through water level management and shoreline vegetation control, is well known. This resulted in a reduction in expenditures for larviciding from US$29 000 in 1935 to US$5 000 in 1940 (data from Hinman, *vide* Public Health Study Team, 1976). The long-term savings due to the use of environmental management techniques for mosquito control in the Tennessee Valley area have been great.

In his review of applied field research in malaria 1975-1980, Haworth (1981) states "When it is considered that source reduction was introduced by McGregor in Lagos in 1900, drainage by Gorgas in Panama in 1906, naturalistic methods for rural malaria (control) were developed by Watson in 1907, and that urban malaria was a rarity in Africa and Asia long before the advent of residual insecticides, it is unbelievable that these methods of control have been almost totally neglected in the past lustrum..." This neglect is illustrated by the fact that only 3 out of 398 articles abstracted by Haworth dealt with environmental or engineering control methods. A recent two-volume treatise on integrated mosquito control methods (Laird and Miles, 1983 and 1985) also found little to report concerning current use of environmental management for mosquito control.

COSTS OF CHEMICAL CONTROL

Many control programmes in countries with endemic vector-borne diseases continue to rely principally on pesticide applications as a major line of defense. The estimated cost of urban insect-vector services in developing countries during 1982-1983 was approximately US$ 639 million (US$ 0.35 global per capita), of which approximately US$ 103 million (US$ 0.06) was spent for pesticides alone (Gratz, 1985). The cost of six major insecticides for national vector control programmes during 1984 in 103 developing countries was about US$ 109 million (*ibid.*). As pointed out by the author, these costs were borne by the least developed of the developing countries, in which the average annual per capita income is often little more than US$ 150.

The cost of controlling the anopheline vectors of malaria, and other insect vectors of disease agents, has increased dramatically during the past several years due to increases in the price of oil-dependent chemical compounds and due to worldwide inflation. In 1982, the United States Agency for International Development, Bureau for Africa, made the following estimate for malaria vector control (Bruce-Chwatt, 1985). In an area with a rural population of one million, vector control by twice-yearly residual spraying, using malathion (50% wdp) at the dosage of 2 g/m2 and a price of US$ 2 500 per tonne, would cost about US$ 1.1 million for insecticide alone

($ 1.1/capita). The cost of transport and equipment would bring the total to about $ 1.7 million, although the latter two items represent capital investments for 3 to 4 years. This estimate does not include the cost of local labour.

The environmental and social costs of different vector control methodologies are difficult to measure; consequently, few attempts have been made to incorporate these costs into cost-benefit and cost-effectiveness analyses. Pimentel *et al.* (1980) estimated the annual indirect environmental and social costs of agricultural pesticide use in the United States about US$ 840 million. Similarly, there may be environmental costs associated with source reduction when it involves ditching and drainage of wetland habitats of waterfowl, other animals, and unique plant communities. These costs should be considered when planning source reduction operations in such areas.

COSTS OF BIOLOGICAL CONTROL

Declines in malaria prevalence rates in Northern Somalia have been attributed to the use of a locally-occurring larvivorous fish (*Oreochromis spilurus spilurus*) against larvae of *A. arabiensis* breeding in rainwater reservoirs (WHO, 1983b). Costing data were, however, not presented. The literature concerning the use of larvivorous fish for mosquito control is extensive. In suitable situations, the stocking of larvivorous fish is obviously less costly than repetitive larvicide applications (Public Health Study Team, 1976: Lichtenberge & Getz, 1985; also see the section on rice field mosquito control below). The present status of research on biological control agents has been reviewed recently (WHO, 1984).

COST-EFFECTIVENESS OF ENVIRONMENTAL MANAGEMENT FOR MOSQUITO CONTROL: CASE STUDIES

Aedes aegypti

Little (1972) compared *A. aegypti* eradication versus vaccination for yellow fever control in the Americas in terms of least-control alternatives; however, the cost-effectiveness of different mosquito control methods was not estimated. The eradication methods considered by Little (1972) are based on work by the Rockefeller Foundation in Brazil in which larviciding with residual insecticides was used in combination with environmental sanitation. The conclusions were that vaccination provides fewer benefits and has higher costs at high discount rates. At discount rates below 10%, eradication is the best alternative.

Singapore's dramatic success in controlling the mosquito vectors of dengue and dengue haemorrhagic fever (DHF) has been well documented (Chan, 1985). An integrated control strategy emphasizing source reduction through environmental management, health education, and law enforcement reduced the *Aedes* house index from 25% in the 1960s to less than 5% in the 1980s. Equally significant was the discovery that an *A.aegypti* ''threshold'' density of about 0.2 females/house was sufficient to sustain a dengue/DHF outbreak even though the combined *Aedes* house index had not exceeded 5%.

Chan (1985) estimated that about 6.1 million Singapore dollars (S$) were spent controlling

Aedes vectors of dengue/DHF, *Culex* vectors of filariasis and Japanese encephalitis (JE), and *Anopheles* vectors of malaria in 1977, and about S$8.2 million in 1981. Estimates of the per capita cost for mosquito control were S$2.66 and S$3.35 in 1977 and 1981, respectively. Staff wages, including allowances and central and municipal provident funds, plus a skill development fund, accounted for 88.3% of the total expenditure in 1977 and 94.2% in 1981. Environmental control measures, especially source reduction which requires the physical removal of water containers from premises, are labour intensive.

As indicated by Chan (1985), it is impossible to separate out the indirect effects of concurrent slum clearance and urban redevelopment in Singapore on mosquito populations. These annual costs amounted to hundreds of millions of Singapore dollars, and slum clearance and urban redevelopment eliminated a tremendous number of mosquito-breeding habitats. Although in no way detracting from Singapore's successful mosquito control programme, it should be emphasized that it is perhaps unrealistic to expect similar dramatic results in comparable areas unless such programmes also are undertaken in concert with massive urban redevelopment schemes.

The Cuban programme for dengue/DHF elimination and *A. aegypti* eradication following the 1981 epidemic, in which 344 203 cases and 158 deaths were reported, has been successful. Dengue was declared eliminated from Cuba on 16 November 1981 and, at that time, the premise index had been reduced from 35 and greater before the epidemic to 0.09 (PAHO, 1983). An integrated control approach was used, i.e., larviciding with temephos, adulticiding with malathion, and source reduction by destroying breeding sites. Cost-effectiveness data for the various components of theintegrated control programme are not available; however, elimination of breeding containers, other than those containing potable water, obviously reduced the amount of insecticide required. For example, 1 256 792 containers were treated with insecticide during treatment cycle 5 (May to August 1982), while 2 215 825 containers were destroyed. During cycle 6 (August to October 1982), a total of 1 979 259 containers were treated and 4 670 786 were destroyed (PAHO, 1983). Although the economic efficiency of destroying breeding sites as a method of source reduction has sometimes been questioned, it appears that the average number of premises treated per individual is competitive with programmes in other countries (PAHO, 1983).

Mosquito control in coastal salt marshes

Provost (1977) reviewed the history of source reduction for the control of salt-marsh mosquitoes on the Atlantic seaboard of the United States. Additional cost-effectiveness data are found in the Public Health Study Team (1976) report. A detailed analysis of control costs in a 175-acre mangrove marsh in the Indian River Mosquito Control District, Florida, is summarized in the latter report. Impounding and dike maintenance resulted in savings of US$ 17 430 or US$ 999.60/acre, over an 11-year period (1961-1972) when compared to the cost of larviciding for the same time period. Extrapolating from these data and applying the cost projections to 4 265 acres of salt marsh that had been impounded in the district during the 10- to 15-year period prior to the study, it was estimated that cost savings of about US$ 500 000 resulted from the use of source reduction methods.

Currently, impoundment management goals are becoming multipurpose, for mosquito control and the enhancement of fisheries resources, wildlife, and water quality. Carlson and Vigliano (1985) discuss the effects of two different water management schemes on mosquito produc-

tion in a salt marsh impoundment in the Indian River Mosquito Control District. Explosive mosquito production may still be possible in revegetated impoundments as a result of rainfall or tidal flooding. In such situations, larviciding may be required to obtain an adequate level of mosquito control.

Shisler and Schulze (1981) compared the costs of mosquito control using permanent and temporary control measures against *A. sollicitans* in New Jersey salt marshes. They concluded that permanent methods were most cost-effective. In contrast, Shisler and Harker (1981) evaluated costs of permanent and temporary control in upland areas and found that not all permanent control projects can be justified economically. Shisler and Schulze (1985) recently reviewed methods for evaluating costs associated with permanent and temporary control for salt marsh mosquito abatement.

DeBord *et al.* (1974) investigated the demand for and cost of salt marsh mosquito abatement for 30 mosquito abatement agencies in Florida, Georgia, Virginia, Delaware,and New Jersey. Analysis of data for 1959-1971 showed that mosquito populations were reduced significantly with both chemical and non-chemical control measures. There were economies of scale with source reduction methods but not with pesticide applications. Results indicated that the use of pesticides was three to four times more effective in reducing mosquito density than permanent control measures. The study did not, however, take into account important seasonal variation in environmental conditions and control activities, the development of insecticide resistance, or the environmental heterogeneity of the five-state region included in the study.

More recent data from one of the agencies included in the above study indicate that permanent control resulting from physical alteration of breeding sites in Chatham County, Georgia, has resulted in savings (Fultz, 1986; Ofiara and Allison, 1985). Similar successes were reported in controlling the pasture mosquito, *P. colombiae*, through ditching and draining dairy pastures in Chatham Country (Fultz, 1976).

Rice field mosquito control

Rice fields are ideal habitats for mosquitoes to breed, including certain vectors of malaria and encephalitis viruses. The magnitude of the problem is illustrated by the fact that rice is the staple food for much of Asia's population, which accounts for more than one-half of the world's population, and that more than 13 million hectares of land in Asia are devoted to rice culture (Mitchell, 1977). Recent reviews have stressed the importance of using environmental management as part of integrated control strategies for rice-field mosquito control (Mather, 1984; Mogi, 1984; Lichtenberg and Getz, 1985).

Data from the Fresno-Westside Mosquito Abatement District (MAD), California, indicate that short-run costs of a parathion-based larviciding programme for rice-field mosquito control average US$ 11.70/acre excluding overhead costs (Lichtenberg and Getz, 1985). At 1983 costs, narrow-spectrum mosquitocides like *Bacillus thuringiensis* or methoprene did not provide economic alternatives to broad-spectrum larvicides such as parathion. Chemical adulticiding may offer a cheaper alternative, but it is less effective than larviciding and both strategies have high long-term costs because mosquito populations become resistant.

The Fresno-Westside MAD uses the mosquito fish, *Gambusia affinis*, in an integrated control programme. Total fish application costs US$ 2.60/acre stocked. This reduces the average

number of chemical larvicide treatments required by 90% and reduces both inspection time and costs/acre by around 65% (Lichtenberg and Getz, 1985).Integrated control is thus economically and ecologically superior to chemical control. The main problem is an insufficient supply of mosquito fish in those districts where most rice is produced.

Mosquito abatement in California

Historically, environmental management through source reduction has been an integral part of mosquito control in California (Reeves, 1986; Mortenson, 1986). Initially, the malaria vector, *A. freeborni*, was the major target; more recently, activities have been directed at the arbovirus vector, *Culex tarsalis*, and certain pest mosquitoes such as *A. nigromaculis*. Each of the latter two species are closely associated with irrigated agriculture.

Sarhan *et al.* (1981) used a simultaneous equation model based on biological and economic data to examine the efficiency of different control methods for *C. tarsalis* and *A. nigromaculis* in the Kern Mosquito Abatement District. A linear programming model was also developed for the Kern district using data from the statistical model plus additional data from the district's records (Sarhan *et al.*, 1980). Summary findings are as follows:

- Pesticide treatment of small mosquito breeding sites was generally more efficient than extensive spraying of large areas.

- Source reduction activities were generally correlated with a reduction in mosquito population levels.

- The pesticide effectiveness index (or resistance of mosquitoes to pesticides) was an important factor in the long-run indirect effect of pesticide control measures.

- Past use of pesticides was directly correlated with mosquito resistance to those pesticides.

- Source reduction activities tended to influence pesticide effectivenes positively.

- Methods for controlling *A. nigromaculis*, ranked according to economic efficiency, are as follows: ditch construction, construction of fills and levees, and treating spot locations with pesticides. Spraying small trouble spots for a 1% reduction in average numbers of *A. nigromaculis* cost 6.05 times more than land fills and levees. For *C. tarsalis*, the rank was: ditch construction, spot treatment with pesticides, construction of sumps and ponds, and construction of land fills, levees, and dikes. Constructing fills and levees for a 1% reduction in the average number of *C. tarsalis* cost 16.03 times more than ditching, 3.37 times more than spot treatments with pesticides, and 5.15 times more than construction of sumps and ponds.

Tax-supported mosquito and vector control agencies in California have traditionally been leaders in implementing new mosquito control technologies. Currently, integrated control is almost universally practiced by these agencies. Separate cost-effectiveness data for chemical, biological, and source reduction control measures are not available. Nonetheless, it may be instructive to examine expenditures and changes in emphasis on source reduction during 1974 and 1984 (the last year for which published data are available).

In 1974, 56 agencies in California reported a total annual budget of US$ 12 925 425 for mosquito control (CMCA, 1975). Only 47 agencies reported fiscal data in 1984; their total annual budget was US$ 24 646 080 (CMVCA, 1985). Using the price deflator for the consumer price index with 1967 set at base 100, the ration for1974: 1984 US dollars is 174.7:3ll.l. Therefore, the 1984 budget is only 7.1% more than the 1974 budget when corrected for inflation.

In 1974, 37 agencies reported expenditures of US$ 2 492 162, or 21.8% of their total budget, for source reduction. Only 33 agencies reported expenditures for source reduction in 1984. Comparable data for these agencies in 1984 are US$ 3 255 952 and 16.1% (table 1). There is, however, a 27% decrease in real US dollars spent for source reduction during 1984 (US$ 1 828 399) after correcting for inflation. Unfortunately, it is impossible readily to derive comparable figures for chemical and biological control expenditures for 1974 from the publication cited (CMCA, 1975); therefore, it is not possible to make meaningful comparisons of changes in expenditures for these components of integrated control between 1974 and 1984.

It would be worthwhile to determine why some of the most sophisticated mosquito control agencies in the world spent 27% less in real US dollars for source reduction in 1984 as compared to 1974. Have other technologies become more cost-effective as habitats amenable to environmental modification continued to shrink or disappear in the face of sustained source reduction efforts over a period of decades?

FUTURE CONSIDERATIONS

With few exceptions, vector control projects are implemented without giving proper attention to the collection of data in a manner that permits economic analyses to be made. Data should be collected in a format suitable for incorporation into a systems framework that will permit economic analysts to derive cost-benefit ratios, economic thresholds of control, and the cost-effectiveness of alternative approaches to control.

Many of the studies on cost-effectiveness have been done in developed countries under conditions of low marginal costs for capital and high marginal prices for labour. These and other key variables are so disparate as to make meaningful comparisons to the situation in developing countries exceedingly difficult. Perhaps information being accumulated by the studies in progress will provide a data base from which extrapolations and projections can be made that will be applicable to developing countries.

Mapping larval mosquito habitats usually is an essential part of integrated mosquito control programmes. Hayes *et al.* (1985) used remote sensing imagery obtained by multispectral scanners aboard earth-orbiting satellites to identify larval habitats around a water impoundment on the Missouri River, United States. There is a great potential for using this technology to identify mosquito habitats associated with impoundments, fresh and salt-water marshes, and other types of wetlands.

Table 1. Comparison of expenditures for source reduction in 1974 and 1984 by California mosquito and vector control agencies* (amounts in US$)

Region	1974 Source Reduction				1984 Source reduction			
	n**	Annual budget***	% of budget	Amount	n**	Annual budget***	% of budget	Amount
Coastal	7	2 334 879	18.5	431 532	7	3 535 347	20.1	711 923
Sacramento	8	2 443 043	20.6	504 156	7	4 299 568	11.4	491 453
N. San Joaquin	5	2 053 433	21.3	437 177	4	3 851 425	19.2	741 281
S. San Joaquin	6	2 388 620	27.7	662 627	7	4 828 230	18.7	901 291
S. California	11	2 223 450	20.5	456 670	8	3 669 740	11.2	410 004
TOTALS	37	11 443 425	21.8	2 492 162	33	20 184 310	16.1	3 255 952

*Data from CMCA (1975) and CMVCA (1985)

**n = number of agencies reporting the use of source reduction for mosquito control

***Annual budget for agencies reporting the use of source reduction for mosquito control

METHODS TO ASSESS AND EVALUATE COST-EFFECTIVENESS IN VECTOR CONTROL PROGRAMMES

by

A.J. Mills
and D.J. Bradley

THE METHODOLOGY OF COST-EFFECTIVENESS ANALYSIS

Background

The economic analysis of disease control programmes has a chequered past, due to the frequency with which it has been used to justify an intervention rather than to evaluate it objectively. Too often the authors of cost-benefit analyses have tackled problems in the spirit of committed advocacy for the programme under consideration, and to the defects of the economic analysis have been added biases so blatant as to cast doubt not only on the validity of their work, but also on that of much valuable earlier work, which, although often undertaken by those with little economics training, was approached in a more objective manner.

Some other analyses carried out by economists have had different limitations. They have focussed particularly upon what is readily and rigorously measureable and have consequently examined relatively minor aspects of the system in elegant detail while making broad and sweeping assumptions about much larger parts of the control programme.

Any reliable economic analysis of a vector-borne disease control programme must be prepared to cope with large uncertainties in the relations between inputs and changes in the output variables, and make some effort to avoid bias in the values used. Some type of sensitivity analysis of the various relationships is needed, along the lines discussed below in connection with assessing the effects of changes in the discount rate. The reader needs to be able to see the consequences of changes in the assumptions about how the variables inter-relate.

Cost-effectiveness analysis and cost-benefit analysis

Before considering the use of cost-effectiveness analysis techniques in vector control programmes, it is important to clarify what is meant by cost-effectiveness analysis and to distinguish it from cost-benefit analysis. In common speech these terms are now unfortunately often used loosely; a further confusion is added by developments in the techniques of cost-effectiveness analysis which bring it closer to cost-benefit analysis.

Cost-effectiveness analysis investigates the best way of achieving a desired objective by comparing effects with costs. Objectives are stated in terms of achieving a desired health effect:

Ms Mills is a health economist working at the Evaluation and Planning Centre of the London School of Hygiene and Tropical Medicine. Professor Bradley is Chairman of the Department of Communicable and Tropical Diseases

for instance reduction in the number of cases of malaria. The question to be answered by cost-effectiveness analysis can be posed in two different ways:

(a) Which of a number of possible interventions will achieve a given health objective for least cost?

(b) Given a fixed budget, which intervention will maximize the achievement of the health objective?

Cost-benefit analysis investigates whether the benefits of a project or programme exceed its costs. It involves identifying, measuring and placing a value on all relevant costs and benefits over an appropriate time-period.

The traditional distinction between cost-effectiveness analysis and cost-benefit analysis is thus two-fold:

- cost-effectiveness analysis is concerned primarily with health effects rather than with any broader benefits stemming from an intervention (e.g., improvements in productivity);

- no attempt is made in cost-effectiveness analysis to place a value on health effects, whereas this is an integral part of cost-benefit analysis.

In recent years, however, refinements have been added to cost-effectiveness analysis which render it a more flexible technique (Department of Clinical Epidemiology and Biostatistics, McMaster University Health Sciences Centre, 1981). In particular, two features have been further developed. First, if some of the non-health benefits of an intervention can be valued, these can be substracted from the costs of the intervention, producing a net cost per health effect. Secondly, interest has grown in ways of adjusting the measure of health effects used (e.g., years of life gained) by adjusting for the quality of those years. Thus, ten years of healthy life gained would be given greater weight than ten years of life gained at the expense of a continuing disability. This refinement is of importance when the cost-effectiveness analysis attempts to compare interventions which have non-comparable health effects, for instance one intervention (e.g., malaria control) reducing episodes of acute morbidity and saving some lives and the other (e.g., schistosomiasis control) having little effect on acute morbidity or mortality but preventing continuing disability.

To illustrate this broader approach to cost-effectiveness analysis, the insert below shows a framework used in Nepal to study the cost-effectiveness of malaria control. Costs are incurred not only by the Government but also by patients, their households and communities. 'Consequences' (a term used to avoid the confusion caused by the terms 'effects' and 'benefits') are of two main types. The first is the immediate health effect of prevention or cure of malaria. The second is any savings in resource use to the government and household expenditure on treatment as a result of preventive strategies for malaria. The inclusion of savings in lost work time as a category of this type of consequence is controversial since it may bias an evaluation in favour of individuals or groups that participate in economic activity and presents practical problems of evaluation. The third, less commonly included type of consequence, changes in quality of life, adjusts the health consequence by a weight which reflects its value to individuals.

COSTS

I Costs to the government of malaria control (i.e. control of the National Malaria Eradication Organization and costs of malaria control borne bz the Integrated Community Health Services Development Project and other Ministry of Health services).

II Costs borne by patients, their households and community members
-payments for treatment and transport to obtain treatment
-loss of time for the patient during the illness prior to cure and for relatives who look after the patient (time may be diverted from household activities, work outside the home and leisure)
-time and money costs of preventive actions taken by households and communities

CONSEQUENCES

I Cases of illness and death averted (through preventive strategies); reduction in in length of illness and secondary transmission prevented (through curative strategies

II Savings in resource use
-savings in government resources that in the absence of curative or preventive malaria control strategies would be required for treatment of cases
-similar savings in individual or household expenditure on treatment and travel
-savings in lost work time

III Changes in the quality of life of patients and their households and of the whole community as a result of malaria control

Figure 1. Framework for the cost-effectiveness analysis of malaria control

PROBLEMS OF ASSESSING THE COST-EFFECTIVENESS OF VECTOR CONTROL PROGRAMMES

Defining the end-point of the control programme

In cost-effectiveness analysis, unlike cost-benefit analysis, there needs to be agreement on the main end-point to be reached. The costs of alternative ways of reaching that end-point can then be compared. This issue is of particular importance in vector control programmes. The end-point can be stated in terms of the vector population (to reduce mosquito density by 95%, for example), or in terms of the prevalence, incidence or severity of the disease transmitted by the vectors to the human population. We would strongly recommend use of the epidemiological, rather than the entomological end-point for several reasons.

First, there are usually alternative non-entomological approaches to disease control and it is important to be able to compare costs of these with costs of environmental management, biological control and chemical control. Secondly, different parts of the vector population of an area may have widely different abilities to transmit disease and it may prove even harder to measure all the relevant aspects of the vector population than to assess the disease being transmitted. Thirdly, even where two or more approaches to vector control are being compared, their effects on vectorial capacity may differ substantially even though vector populations may be equally reduced. For example, residual insecticides, by reducing mosquito adult life expectancy, may reduce transmission of disease more than does an environmental management intervention that has an equal effect on insect density.

Lastly, and perhaps most important, the goal of vector control is reduction in human disease, and this is a real test of any programme. If disease is not reduced, then the programme is not effective.

Programme size

The end-result of cost-effectiveness analysis is an average cost per unit of health effect. It is common, however, for the average cost to differ, depending on factors such as the size of the programme and the incidence or prevalence of a particular disease. A certain level of cost is usually necessary however low the level of activity of the programme since a certain proportion of costs are fixed: for instance buildings, equipment, transport, and a core-staff. An increase in activity can then take place requiring expenditure only on variable inputs - for instance drugs and insecticides. Thus, unit costs will start to fall. Economic theory hypothesises that at some stage unit costs will rise again, perhaps because if we are considering a surveillance system, it becomes increasingly time-consuming and expensive to trace the last few cases.

There is little evidence on the behaviour of costs as activity levels change in vector control programmes. An analysis was done for the spraying programme of the Nepal Malaria Eradication Organization. In areas where DDT was sprayed fixed costs amounted to just under 25% of total costs, and in a malathion area only to 14% (due to the higher cost of malathion). These are relatively low fixed costs for a health programme and can be explained in the following way. In the spraying programme, spraymen are recruited and district staff diverted from other duties when required, thus costs respond fairly immediately to a change in the level of spraying activity. In contrast, in the surveillance programme which absorbs the bulk of malaria control costs, fixed costs are extremely high because of the extensive infrastructure required for surveillance regardless of the level of activity (e.g., number of slides taken or cases detected).

It is thus extremely important, when considering the cost-effectiveness of vector control programmes, to look at the cost per unit of effect for different sizes of the programme, to check whether size affects the cost-effectiveness estimates and the choice of intervention.

Multiple benefits and joint costs

In cost-effectiveness analysis, particular difficulties are raised where an intervention has several benefits beyond disease reduction. Insecticidal control of endophilic insect vectors of disease is a clearly defined "add on" intervention that will, it is hoped, kill mosquito vectors of disease and will have few other effects. Perhaps bed-bugs in the houses, not vectors but an

unpleasant nuisance, may also be killed, but on the whole the intervention is a single discrete activity and it has one substantial effect.

By contrast, environmental management is rarely a discrete activity. It might, for instance, involve changes in the design of a water resource development so that fewer breeding places for vectors exist. If the issue has been taken into consideration at the early design stage, as is recommended, it will not even involve changes but will affect the initial design of the irrigation scheme or other resource development. Identification of the cost attributable to vector control is therefore both difficult and arbitrary.

Similarly, the benefits are likely to be diverse. In the best examples of environmental management, as in the irrigated rice fields of Leyte, Philippines, improved agricultural practices simultaneously raise the rice yield and make the fields unsuitable for the snail intermediate hosts of *Schistosoma japonicum.* There is no obvious division of the activities of agricultural improvement between rice production and snail control.

This problem of the allocation of 'joint costs' is common and substantial in vector control programmes. Where a project has a number of different functions or purposes - for instance both improved irrigation and vector control - a judgement is required for each project on the most appropriate method of allocation of joint costs. This should preferably be done by someone who has no heavily vested interest in the outcome of the calculations. The alternative methods of allocation are as follows:

(a) If one of the purposes of the project is clearly pre-eminent, the whole project cost can be attributed to that and any contribution the project makes to another purpose - for instance health - can be regarded as a costless 'bonus'. For instance, in the Philippines example given above, if the rice yield increase is substantial it may be practicable to allocate the whole cost to agriculture on the grounds that even if schistosomiasis had been absent initially, the improvements would still have been worthwhile.

(b) If one of the purposes is clearly the main purpose, but the project has been modified to enable a subsidiary aim to be pursued at the same time, then the additional costs of the modifications can be attributed to the subsidiary aim, the remainder being allocated to the main purpose.

(c) If the purposes cannot be clearly divided into main and subsidiary, then total costs can be divided pro-rata with some measure of workload or throughput.

(d) Alternatively, fixed costs could be left unallocated and variable costs attributed to the purpose which gives rise to them. This procedure does not produce an estimate of the total cost of each purpose.

It may be difficult in a particular situation to decide which method is most appropriate and the various alternatives can give very different results. For instance, to give another example from Nepal, in areas where malaria control has been integrated with general health services, spraying supervision is done by health post staff, released from their normal duties. Should spraying be allocated only the incremental costs associated with the supervision, that is the actual number of days spent, or should it also take a share of the fixed costs of the health centre - for instance of the buildings and staff time spent in managerial and administrative tasks? The two methods may produce very different costs, especially when fixed costs are a large proportion of total costs.

The balance between capital and recurrent expenditure

It is commonly the case that environmental management of vectors is associated with very heavy initial capital costs for engineering works and a low maintenance cost, by contrast with insecticidal or chemotherapeutic programmes which have large annual recurrent cost implications. The normal practice in cost/effectiveness studies is to assume that costs (and often effects also) are of less value the further into the future they occur. Thus costs are discounted, through the application of a discount rate, to obtain their present value.

This can cause problems because the exact level of the discount rate can be difficult to determine and variations in the discount rate can affect the choice of the intervention method. This is particularly likely where alternative interventions differ greatly in the timing of costs and effects. For instance, Cohn (1973) compared the present value of the costs in India of malaria control and malaria eradication, the former requiring continuing steady expenditure, and the latter high initial expenditure (see Table 1). At lower discount rates, eradication is

Table 1. Present value of the costs of malaria control and eradication in India

Discount rate %	Control for 30 years Rs (m)	Eradication Rs (m)
6	930	654
8	761	613
10	636	574
12	545	542
14	473	508
16	417	479
18	382	457

Source : Cohn (1973)

preferable on cost grounds. As the discount rate increases however, costs in future years are given increasingly less weight and above 12%, control becomes preferable. Since vector control through irrigation engineering usually requires a very large initial outlay and little continuing expenditure, a similar effect is possible. Choice of intervention method essentially demands careful judgement of the most appropriate discount rate for the country concerned.

OBTAINING COST INFORMATION

Health programmes are notorious for their absence of financial data. An important first step in cost-effectiveness analysis is thus costing a programme. Cost information is required on both government and private (patient, household, community) costs, including both recurrent and capital items.

Two approaches are possible to obtaining information on government costs, the choice depending on the availability of information and the nature of the programme being costed.

The first approach is to start from government accounts of expenditure and to add to them any omitted items such as the annuitized value of capital. Depending on the approach to shadow pricing being adopted, the accounts may need further adjustment in order that the figures reflect the social opportunity cost of the inputs. If only part of the programme is concerned with vector control, then the share of programme cost attributable to vector control needs to be established. If a programme budget system is in use this may be a relatively easy task; if not, detailed field investigations of time allocation patterns of staff and use of supplies and equipment will be required (see for instance, Kaewsonthi and Harding, 1984). Even if a programme budget system is in use, visits to field units (for instance district headquarters vector control teams) are indispensable to check the accuracy of a programme budget and to supplement cost data with information on levels of activity. Where a national programme is being analyzed, it is often useful to supplement a national level analysis with detailed case-studies of costs in a sample of districts or field units.

The second approach is most relevant where a small local project is being costed or where the costing is being done prior to implementation of the project. A list is made of the quantities of physical inputs required by the project (staff, buildings, supplies, etc.) and these are then priced and added up. For obvious reasons, this is often called the 'ingredients' method (Levin, 1983).

Information on private costs, for instance out-of-pocket payments by patients, is often not readily available and a small survey may be required.

Costing vector control programmes may involve two particular costing problems. First, where community labour is used in environmental management, there is the problem of how to value the opportunity cost of such labour. In principle, it is the value of the production foregone (the marginal product). In practice, therefore, a crude approach to valuing the opportunity cost of labour is often employed, for instance taking the prevailing wage for unskilled labour.

The second problem is that the introduction of new vector control methods such as environmental management using community participation may involve major changes in behaviour for existing vector control staff. Adequate allowance needs to be made for the costs of changing behaviour, for instance the cost of refresher training.

Cost information, especially when only part of a larger programme is being analyzed, is rarely as precise as would be wished. It is, therefore, extremely important in any cost-effectiveness analysis to do a sensitivity analysis, that is to check whether plausible changes in the values of the main variables (e.g., values of the cost components and costing assumptions, as well as estimates of effects) would affect the conclusions of the analysis.

SECULAR CHANGES

There are several specific problems encountered in vector control programmes that can be handled empirically and the approach adopted justified, provided the reader is clearly told what has been done. Assumptions, approximations, and guesses should be clearly indicated as such, rather than conveniently buried in the calculations. Biological uncertainties are, however, particularly intractable, short of doing a field experiment. As a result of energetic control ef-

forts, there may have been changes in the environment and fauna so that even if active control measures are discontinued, the situation may not revert. This makes estimating the effectiveness measure 'cases prevented' extremely uncertain. For example, although malaria vector control was needed to make part of the Nepalese Terai habitable, it is not clear what situation would develop if all vector control were to be discontinued: the increased population density has led to persistent ecological changes and the environment may be unsuitable for re-colonization by the original vector, *Anopheles minimus*. In Uganda, following strong insecticidal control of *Simulium damnosum*, there have been suggestions that recolonization of the Nile has been by a less effective vector of onchocerciasis.

These examples of the wide-ranging effects of vector control are also instances of long-term secular changes, which may well occur also during the life-time of major irrigation schemes or other major water resource development schemes. For instance, the process of tree decay, eutrophication, rising then falling fish yields affecting the resident human fishing population, and the rapid rise and slow decline of waterweed habitats for the snail intermediate hosts of *Schistosoma* spp., all in Lake Volta, Ghana, have led to a 'moving baseline' over some 15 years.

It is, nevertheless, usually possible to make a reasonable attempt at a cost-effectiveness analysis of the possible alternative ways to achieve a given improvement in the vector-borne disease situation by the approach set out in this paper. To avoid needless controversy and to aid improvement of work on cost-effectiveness, particular attention should be paid to (i) stating all assumptions and estimates clearly, (ii) exploring the effect of changed estimates of difficult variables upon the outcome, and (iii) making the calculations as explicit and accessible as possible. The continuing rapid development of water resources in the Third World provides many situations where cost-effectiveness analysis of vector-borne disease control can be usefully developed and can provide practical guidance.

REFERENCES

Mather

FAO, 1986. *Consultation on Irrigation in Africa*, FAO Irrigation and Drainage Paper 42, Rome

Rosenfield, P., 1986. *The economics of parasitic diseases: research priorities*, WHO/TDR unpublished document , Geneva

Small

Abel, M.E., 1976. Irrigation systems in Taiwan: management of a decentralized public enterprise, *Water Resources Research 12*, 3: 314-348.

Adams, F., 1952. *Community organization for irrigation in the United States*,, FAO Development Paper 19, Rome

Bergman, H., 1984. Management structures in Mediterranean irrigation, *Irrigation Management Network Paper 9c*, Overseas Development Institute, London

Bothrall, A.F., 1976. *Comparative study of the management and organization of irrigation projects*, World Bank Research Project no. 334, paper no. 2: Pilot field study in North West India, with special reference to Chambal Project, Rajasthan, Overseas Development Institute, London

Bothrall, A.F., 1978a. *Comparative study of the management and organization of irrigation projects*, World Bank Research Project no. 671/34, report no. 7: Field study in Pakistan: Lower Jhelum Canal and Scarp II Circles, Sargodha District, Punjab, Overseas Development Institute, London

Bothrall, A.F., 1978b. *Comparative study of the management and organization of irrigation projects*, World Bank Research Project no. 671/34, report no. 6: Field study in Taiwan: Yunlin Irrigation Association, Overseas Development Institute, London

Carruthers, I., 1985. *Irrigation pricing and management*, report submitted to the US Agency for International Development, contract no. OTR-0091-C-00-4466-00, Devres, Inc..

Easter, K.W. , 1985. *Recurring cost of irrigation in Asia: operation and maintenance (O&M)*, final report for the US Agency for International Development, Water Management synthesis II, contract no. CID/AID-DAN-4127-C-00-2086-00, East-west Center, Honolulu, Hawaii.

Kelly, W.W., 1982. Irrigation management in Japan: a critical review of Japanese social science, Rural Development Committee, *Occasional Paper Series no. 12*, Cornell University, Ithaka

Khan, H.R., 1981. *Irrigation water pricing in Bangladesh*, proceedings of the Expert Group Meeting on Water Pricing (Bangkok, 13-19 May 1980), UN Water Resources Series no. 55: 55-56

Kimura, T., 1977. Japan - 1. In: *Farm Water Management for Rice Cultivation*, part IV, country reports, chapter 5: 248-266, Asian Productivity Organization, Tokyo

Nickum, J.A., 1982. *Irrigation management in China*: a review of the literature, World Bank Staff Working Paper no.545, Washington D.C.

Okamoto, M., Ogino, Y., Satoh, M. and Hirota, J., 1985. Land improvement districts as irrigation associations in Japan today, *Journal of Irrigation Engineering and Rural Planning* 7: 32-35.

Pawar, J.R., 1985. *Recurrent cost study of operation and maintenance of irrigation systems in Maharashtra, India*, mimeographed document, Mahatma Phule University, Maharashtra.

Pelissier, F. 1968. *Water charges for irrigation in France: methods and principles*, unpublished document ECA:WR/68/387a) of the Third session of the FAO/European Commission on Agriculture Working Party on Water Resources and Irrigation.

Silva, A.T.M. *et al.*, 1985. *Study of recurrent cost problems in irrigation systems: Sri Lanka*, final report to the US Agency for International Development.

Small, L.E., Adriano, M.S. and Martin, E.D:, 1986. *Regional study on irrigation service fees*, final report, International Irrigation Management Institute, Digana Village, Sri Lanka.

Thompson, S.J., 1985. *National Irrigation Programs in the United States: a history of project financing and repayment*, mimeographed document, Department of Development Sociology, Cornell University, Ithaca.

USA Congress, Office of Technology Assessment, 1983. *Water-related technologies for sustainable agriculture in US arid/semi-arid lands*, OTA-F-212, Washington D.C.

Westgate, R.A., 1985. Review of literature - the importance of O&M, appendix B to: R*ecurring cost of irrigation in Asia, operation and maintenance (O&M)* , by K.W. Easter (ed.), op.cit.

World Bank, 1983. *Mexico, irrigation subsector survey - first stage improvement of operating efficiencies in existing irrigation schemes*, report no. 4516-ME by E. Gazit *et al.*, for the Agriculture Division of the Latin America and the Caribbean Regional Projects Department

Wolf, J.M., 1985. *Cost and financing of irrigation system operations and maintenance in Pakistan*, case study series, International Irrigation Management Institute, Digana Village, Sri Lanka.

Mitchell

Barlow, R. and Grobar, L.M., 1986 (re-issue). *Costs and benefits of controlling parasitic diseases*, World Bank, PHN Techn. Note 85-17, 127p.

Carlson, D.B. and Vigliano, R.R., 1985. The effects of two different water management regimes on flooding and mosquito production in a salt marsh impoundment, *J. Am. Mosq. Control Ass. 1*: 203-211

Chan, K.L., 1985. Singapore's dengue haemorrhagic fever control programme: A case study on the successful control of Aedes aegypti and Aedes albopictus using mainly environmental measures as a part of integrated vector control, *SEAMEO Publication no. 45*. Tokyo

DeBord, D.V., et al., 1975. Demand for and cost of coastal salt marsh mosquito abatement, North Carolina Agric. *Exp. Stat. Tech. Bull. 232*. 85p.

Fultz, T.O., 1976. Mosquito control measures to meet special local needs, Florida Anti-mosq. Ass., *Proc. 47th Ann. Meeting*, pp. 6-7.

Fultz, T.O., 1986. Economics of mosquito control in Chatham County, Georgia, *Proc. N.J. Mosq. Control Ass. 73*.

Gratz, N.G., 1985. The future of vector biology and control in the World health organization, *J. Am. Mosq. Control Assoc. 1(2)*: 273-278

Haworth, J., 1981. *Inventory of applied field research in malaria.* UNDP/World Bank/WHO Special Programme for Research and training in Tropical Diseases, 125p.

Laird, M. and Miles, J.W., 1985. *Integrated mosquito control methodologies*, Vol. 2: biocontrol and other innovative components, and future directions Academic Press, New York, 444p.

Lichtenberg, E. and Getz, W.M., 1984. Who should pay for rice field mosquito control?, *California Agriculture 38 (11-12)*, 4-6.

Lichtenberg, E. and Getz, W.M., 1985. Economics of rice field mosquito control in California, USA, *Bioscience 35 (5)*: 292-297.

Little, A.D., Inc., 1972. *The prevention of diseases transmitted by* Aedes aegypti *in the Americas - a cost-benefit study.* Report prepared for the Pan-American Health Organization, 175p.

Mather, T.H. and That, T.T., 1984. *Environmental management for vector control in rice fields*, FAO Irrigation and Drainage Series no. 41, Rome

Mitchell, C.J., 1977, Arthropod-borne encephalitis viruses and water resource developments, *Cah. ORSTOM, ser. Ent. méd. et Parasitol. 15 (3)*: 241-251

Mogi, M., 1984. Mosquito problems and their solution in relation to paddy rice production, Protect. *Ecology 7:* 219-240.

Mortenson, E.W., 1986. An historical review of mosquito prevention in California, Part I (1904-1046), *Calif. Mosq. Vect. Control Assoc. Proc. 53rd Meeting*, pp 41-46.

Ofiara, D.D. and Allison, J.R., 1985. The use of present value criterion applications in making mosquito control decisions, *J. Am. Mosq. Control Assoc. 1(3):* 284-294.

Pan American health Organization, 1983. The Cuban Aedes aegypti campaign: a year later, *Epidem. Bull. (PAHO) 4(2)*: 8-10

Pimentel, D. et al., 1980. Pesticides: environmental and social costs, pp. 99-158. In: Pimentel, D. and Perkins, J.H., eds., *Pest Control; Cultural and environmental Aspects*, Westview Press, Boulder. Colorado, 243p.

Provost, M.W., 1977. Source reduction in salt marsh mosquito control: past and future, *Mosq. News 37(4)*: 689-698.

Sarhan, M.E., et al., 1980. Economic evaluation of mosquito control programs, *California Agriculture 34 (11-12)*: 22-24.

Sarhan, M.E., et al., 1981. *Economic evaluation of mosquito controland narrow-spectrum mosquitocide development in California*, Giannini Foundation Research Rpt. no. 330, 90p.

Shishler, J.K. and Harker, W., 1981. Source reduction as an economical approach to mosquito management, *Mosq. News 41*: 419-423.

Shishler, J.K. and Schulze, T.L., 1981. Comparison of costs for mosquito control on New Jersey disposal sites, Mosq. News 41: 465-469.

Shishler, J.K. and Schulze, T.L., 1985. Methods for evaluation of costs associated with permanent and temporary control methods for salt marsh mosquito abatement. *J. Am. Mosq. Control. Assoc. 1(2)*: 164-168.

World Health Organization, 1980. Environmental Management for Vector Control, fourth report of the WHO Expert Committee on Vector Biology and Control. WHO Technical Report Series no. 649, Geneva.

World health Organization, 1983a. *Integrated Vector Control*, Technical Report Series no. 688, WHO, Geneva.

World Health Organization, 1983b. *Report of the steering committees of the Scientific Working Groups on malaria June 1980- June 1983*, document TDR/MAL/SC-SWG (80-83)/83.3.

World Health Organization, 1984. *Report of the seventh meeting of the Scientific Working Group on biological control of vectors*, document TDR/BCV/SWG-7/84.3.

Mills and Bradley

Cohn, E.J., 1973. Assessing the costs and benefits of anti-malaria programs: the Indian experience, *American Journal of Public Health 63* (12): 106-109.

Department of Clinical Epidemiology and Biostatistics, McMaster University Health Sciences Centre , 1981. How to read clinical journals: VII. To understand an economic evaluation, *Canadian Med. Ass. Journal, 124*: 1156-1162.

Kaewsonthi, S., and Harding, A., 1984. Cost and performance of malaria surveillance in Thailand, *Soc. Sci. Med. 19 (10)*: 1081-1097.

Levin, H.M., 1983. *Cost-effectiveness: a primer*, Sage publications.

Mills, A.J., 1986. *The cost-effectiveness of malaria control methods in Nepal*, Evaluation and Planning Centre, London School of Hygiene and Tropical Medicine.